# SEDMv2 Project Overview

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M. Rigault
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J. Purdum
A. Reedy


# Son of SEDM (the sequel)

Don Neill

# Outline

- Introduction
- History
  - Origin Story
  - Evolution of an Idea
  - World Domination!
  - Setbacks
  - Christmas Present
- Fabrication during a Pandemic
- Installation before/after a Fire
- Current Status

# Introduction

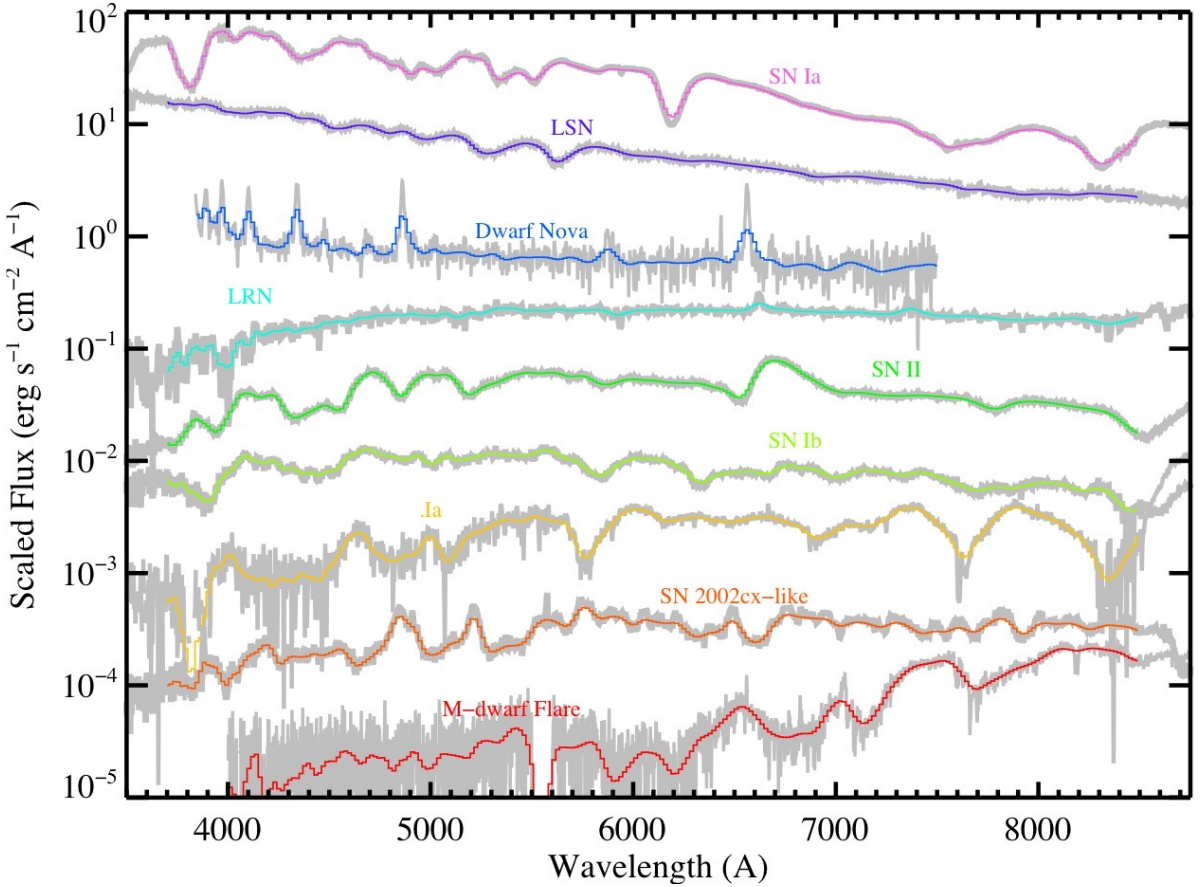
- Here to optimize scientific return of SEDMv2
- Strong consortium of institutions
  - Caltech
  - Goddard / U Maryland
  - University of Minnesota
  - Northwestern University
  - Space Telescope Science Institute
- Start communication and the flow of ideas
  - Open source model for operations/software improvements
- Set scientific goals and derive a set of tools/protocols
- Other talks by Yashvi, Michael, Reed, Josiah
- History to provide context

# Introduction: Cast of Characters

- Caltech
  - Shri Kulkarni: Principal Investigator
  - Don Neill: Instrument Scientist
  - Michael Feeney: initial mechanical design
  - Lauren Fahey: final mechanical design, procurement
  - Jason Fucik: optical design and procurement
  - Yashvi Sharma: Operations Scientist, data analysis pipeline, installation
  - Reed Riddle: Telescope Scientist, software design and development
  - Josiah Purdum: Operations Engineer, installation and operations
  - Alex Reedy: installation
- University of Minnesota
  - Michael Coughlin: Project Scientist, scheduling software, telescope simulator
  - Sam Corey, Sam Hastings: telescope simulator
  - Tyler Barna, Brendan King: installation

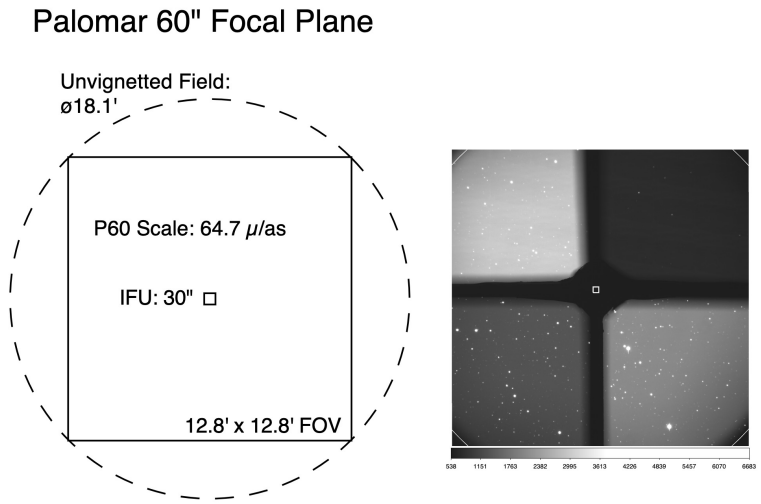
# History: Origin Story

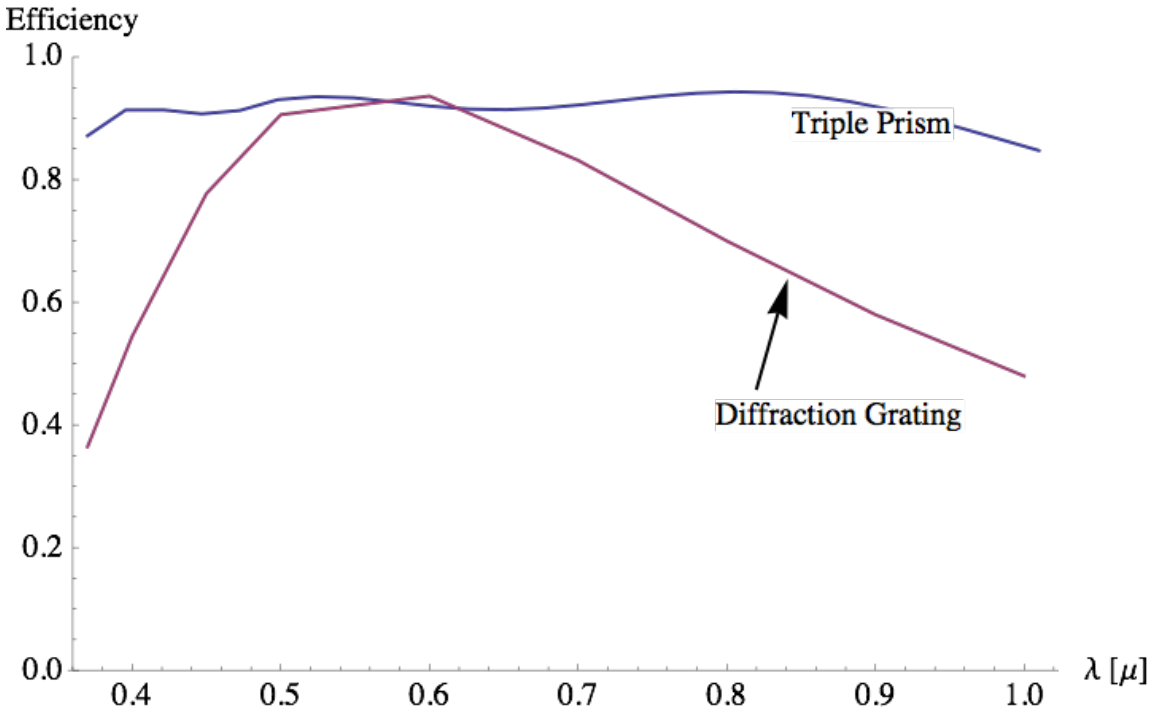
- Palomar Holiday Retreat, 2009
  - Shri Kulkarni, Robert Quimby, Nick Konidaris
  - Problem: 100s discoveries/night with PTF
    - Run allocations several nights per month
    - How to classify?
  - Dedicated single purpose spectrograph
  - What resolution will suffice?
    - R ~ 100 -> high throughput
  - P60 was robotic for GRB Cam (Cenko, et al.)
  - Very low-cost origins: Nikon lenses with a budget of $20k



# History: Origin Story

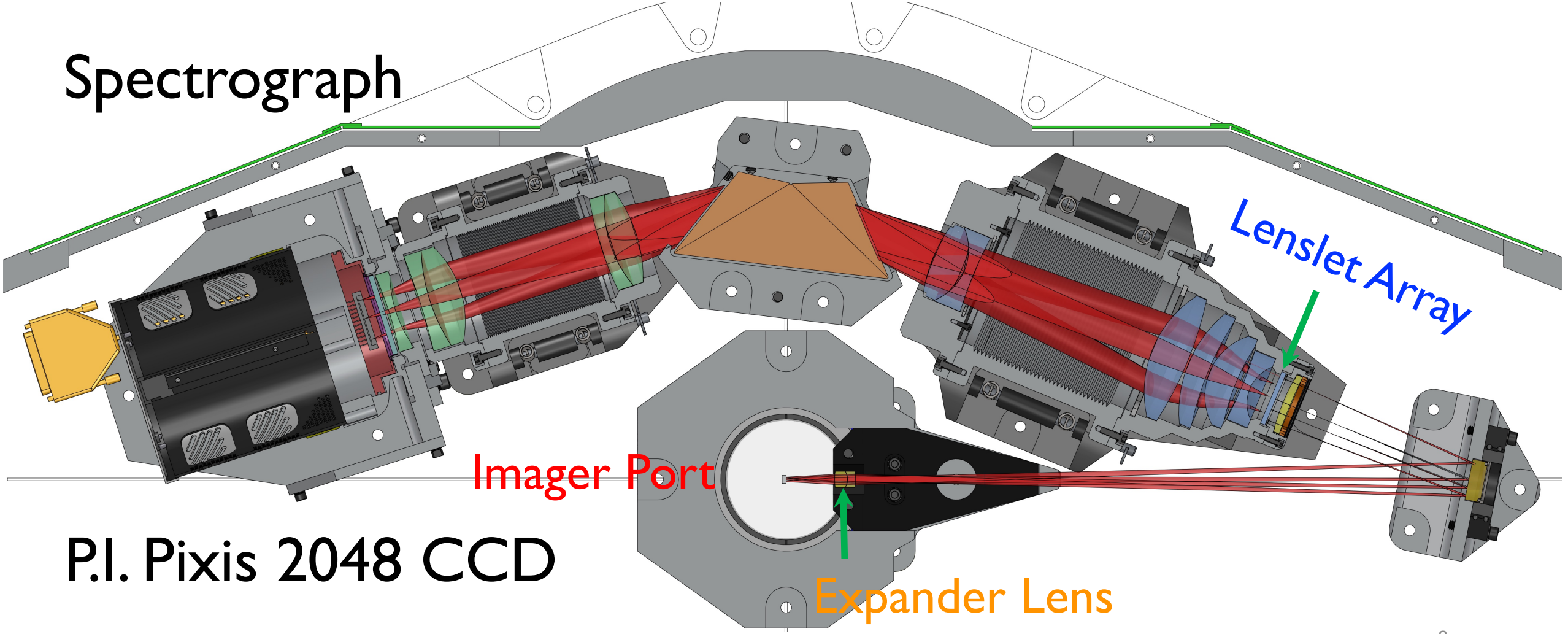
- NSF ATI grant #1106171
  - July 2011, $675K
  - PI: Nick Konidaris
    - R. Quimby
    - C. Chong-Ngeow
    - S. Ben-Ami,
    - R. Dekany
    - S. Kulkarni
  - Custom optics, COTS detectors, Tri-prism
  - Added imaging channel



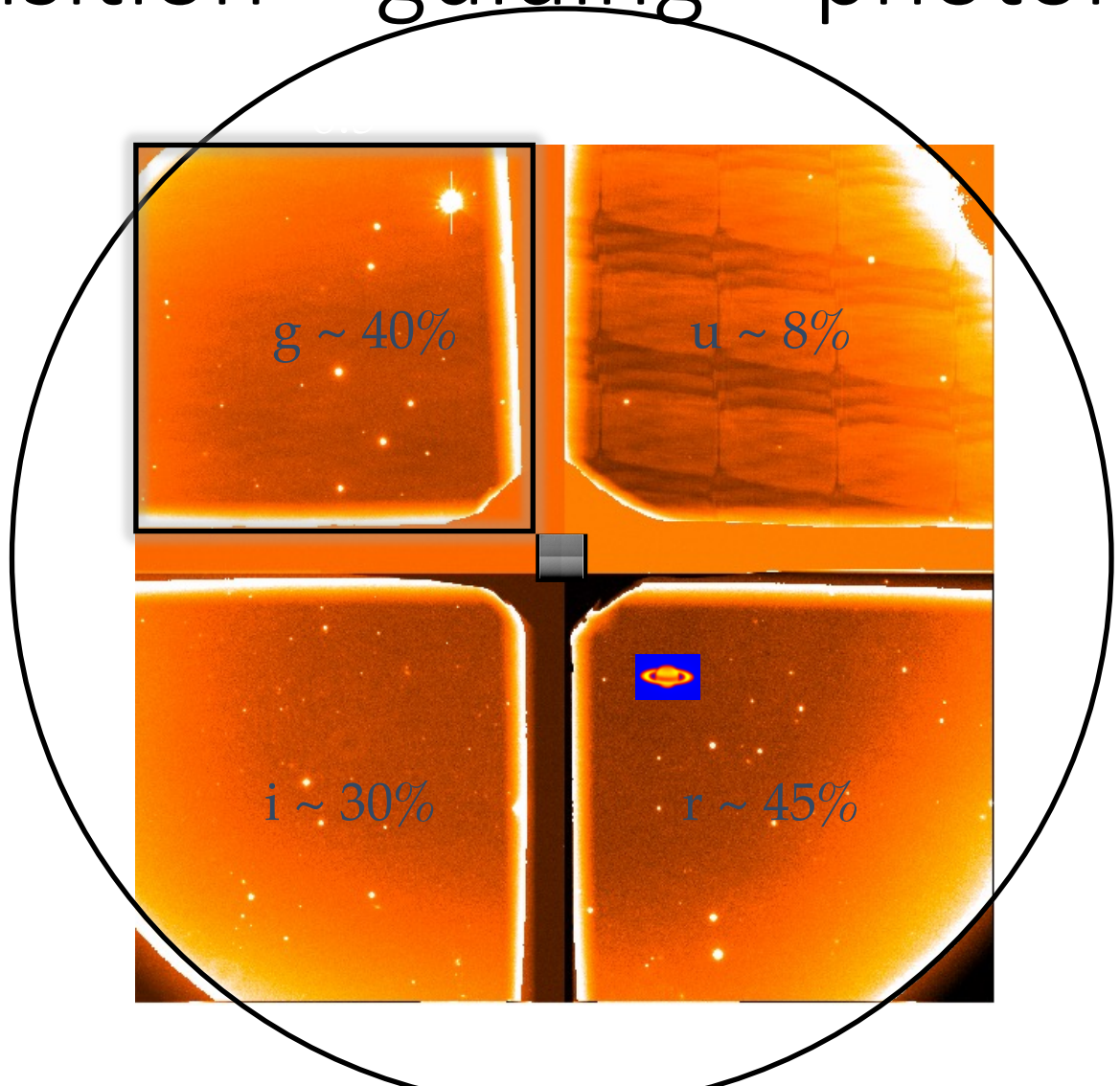
# Hyperspectral imaging spectrograph

## Spectrograph

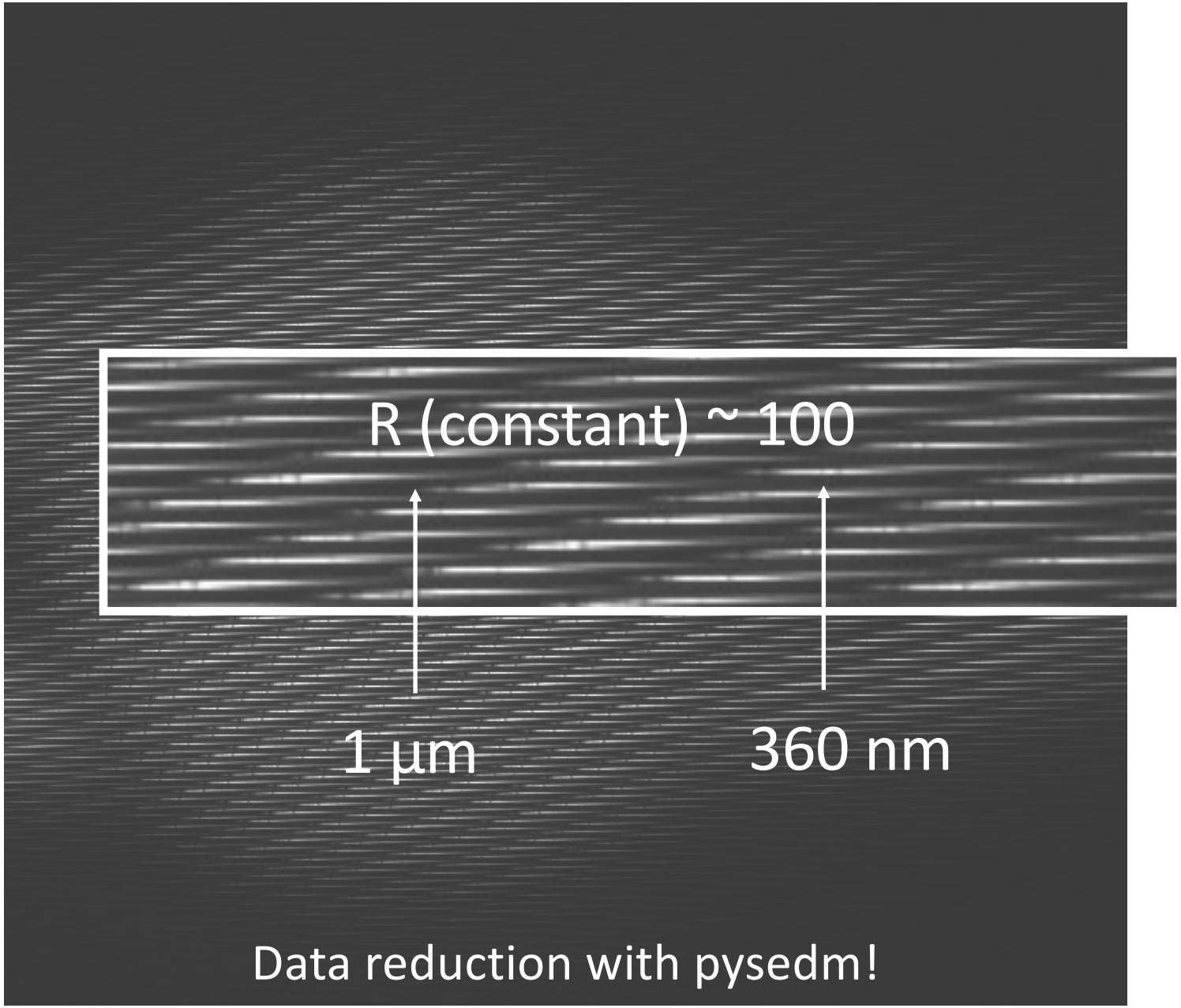



## P.I. Pixis 2048 CCD

# Rainbow camera (RC) imager: acquisition + guiding + photometry




Guide image
WCS solved for
object location
in IFU for DRP

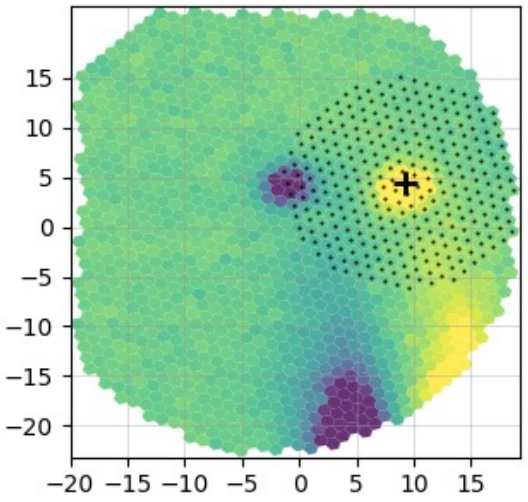

R (constant) ~ 100
1 µm
360 nm
Data reduction with pysedm!

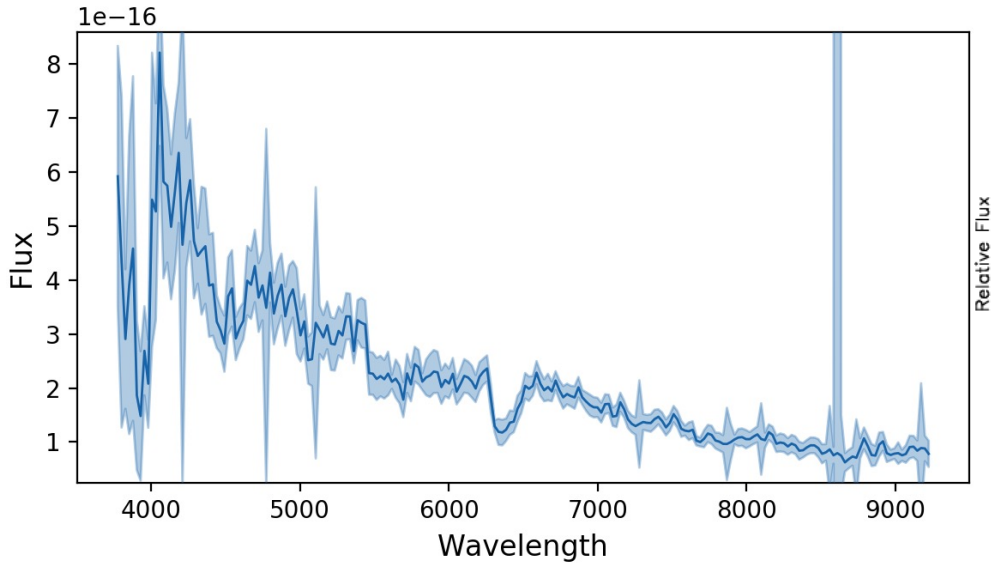
# History: Evolution of an Idea

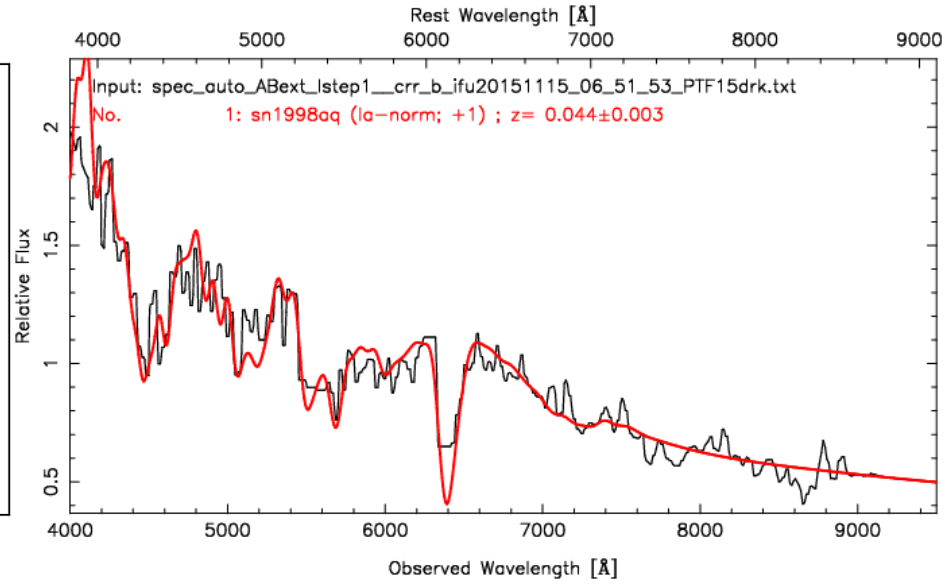
- First light in June, 2013
- Problems encountered:
  - High scattered light
  - Some mechanical stability issues: MLA/optics movement
  - Channel parfocality
  - Not reaching goal: classify 20.5 mag target in <= 3600s
- First public Classification on 3 May, 2014
  - CSS140425: SN Ia, z=0.03, 16.4 mag
  - Ok for bright targets ~ 16 mag
  - Operations not yet automated, calibrations very manual
  - Operated from P60 control room

# History: Evolution of an Idea: A/B exposures

November 15, 2015



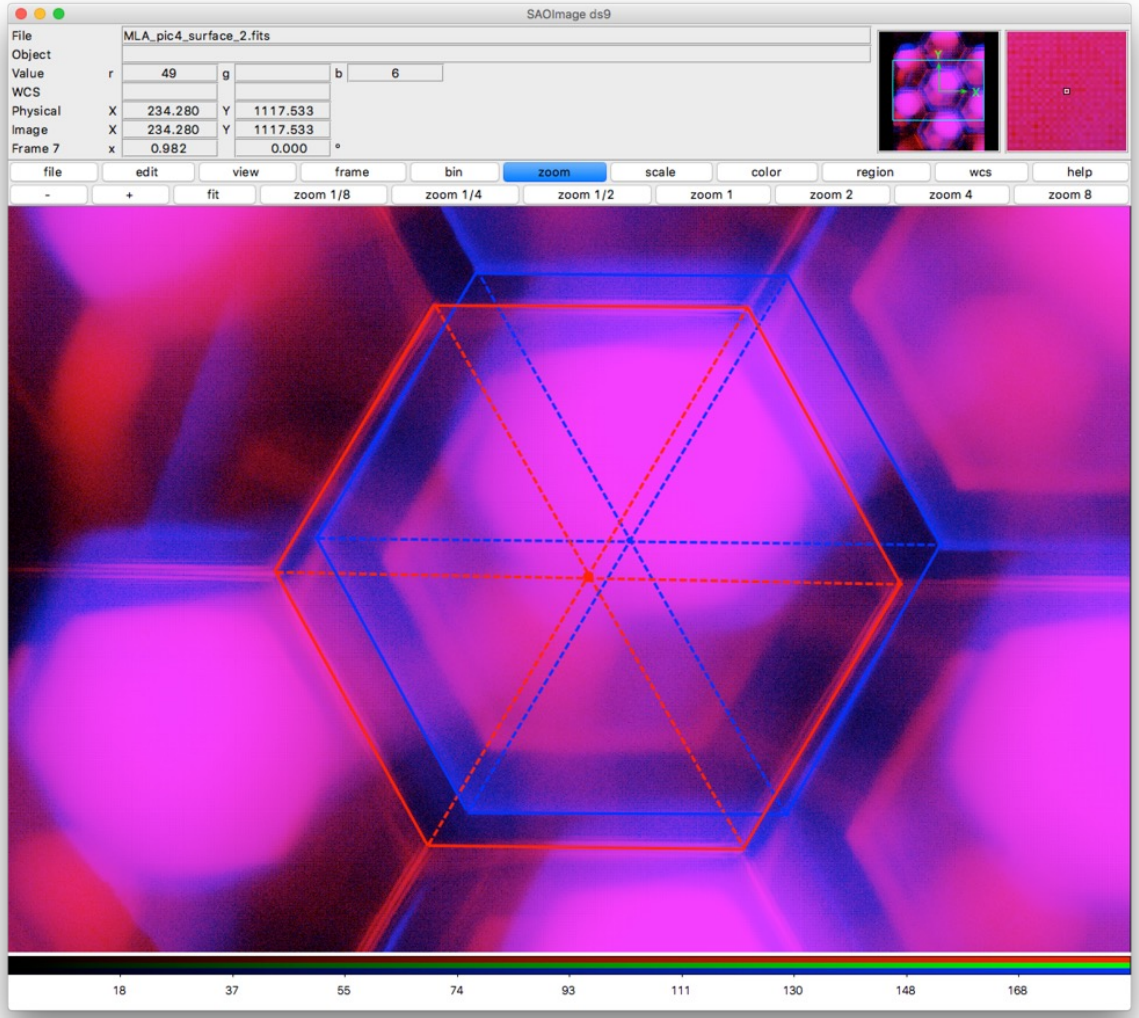




PTF15drk 1200s+1200s, SNIa @ z=0.04, 18.0 mag

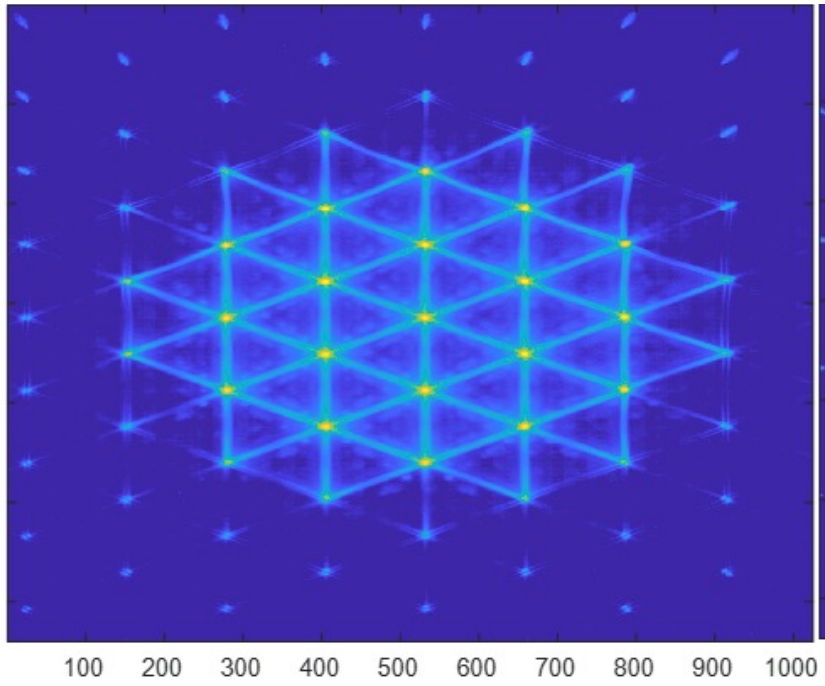
# History: Evolution of an Idea: MLA redesign

- Original MLA was double-convex
  - Alignment issues in manufacturing
- New MLA is plano-convex
  - No alignment issues

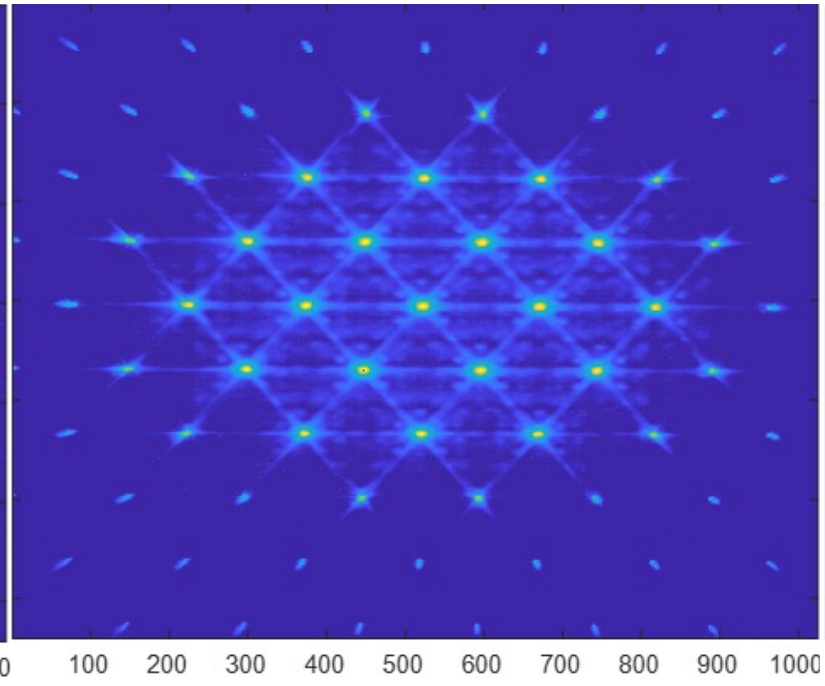


# Compare Normalized Image of micro-pupils (log scale)

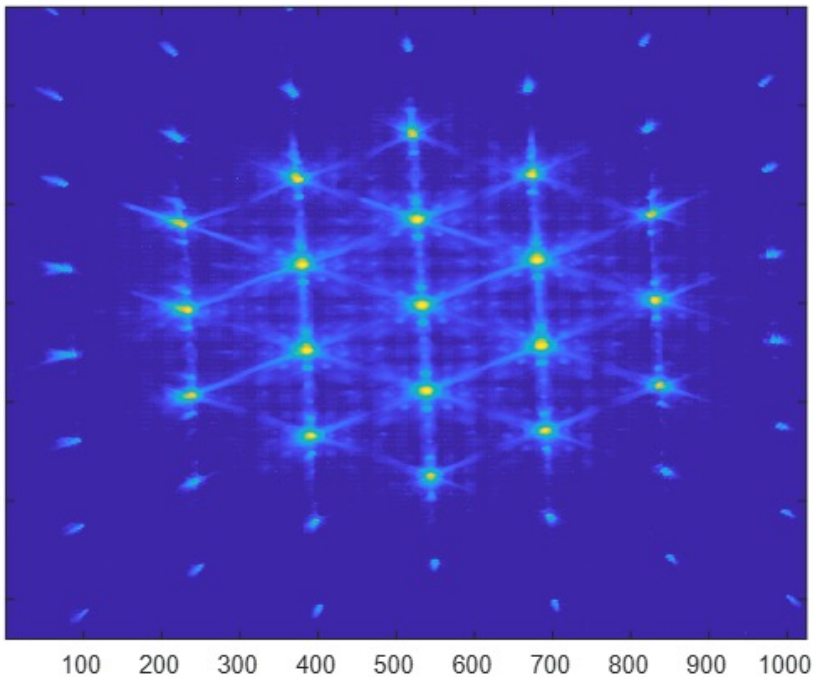
**Original MLA**




**Jenoptic A (520)**




**Jenoptic D (606)**



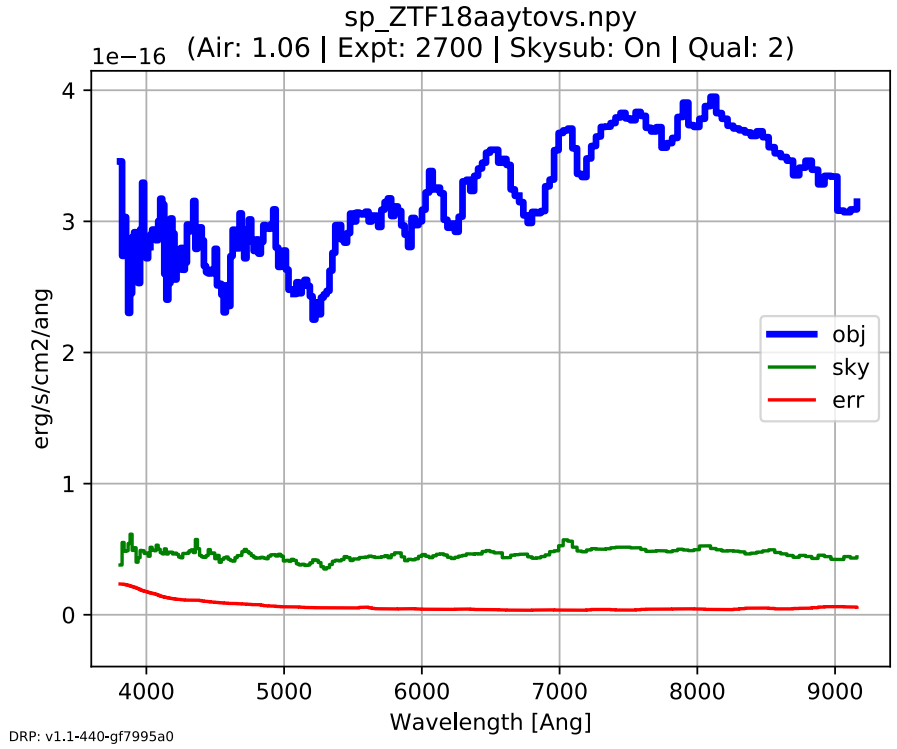

New MLAs have have less power in the “wings”.
Masking cuts throughput but controls light better.

**Installed Jenoptic A**

# MLA Upgrade Performance

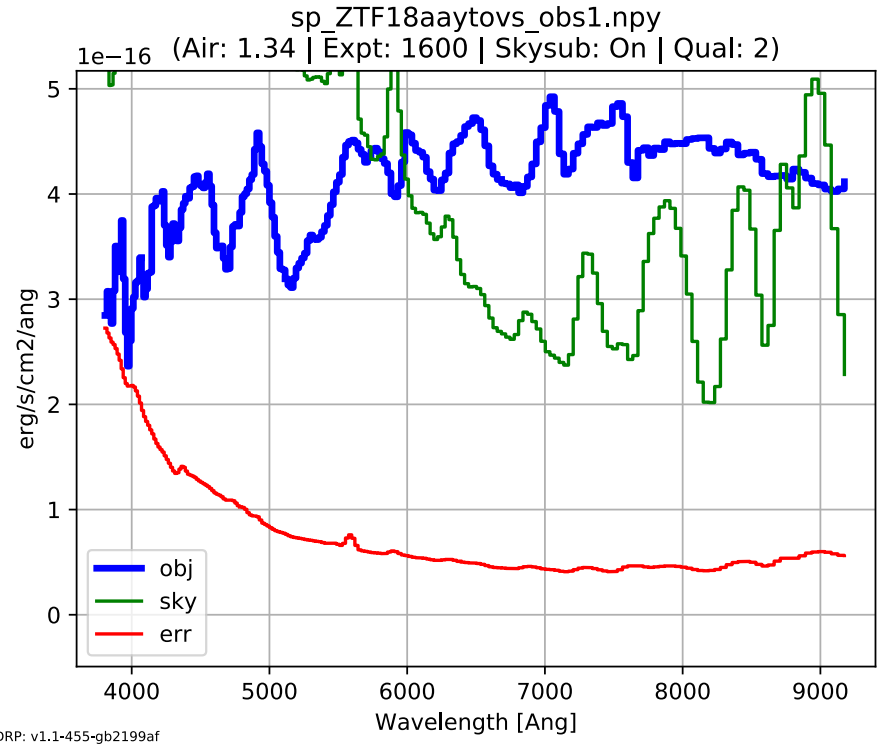
**Old MLA: 2018 June 17**

**A/B pair 18.5 g mag  2700s**

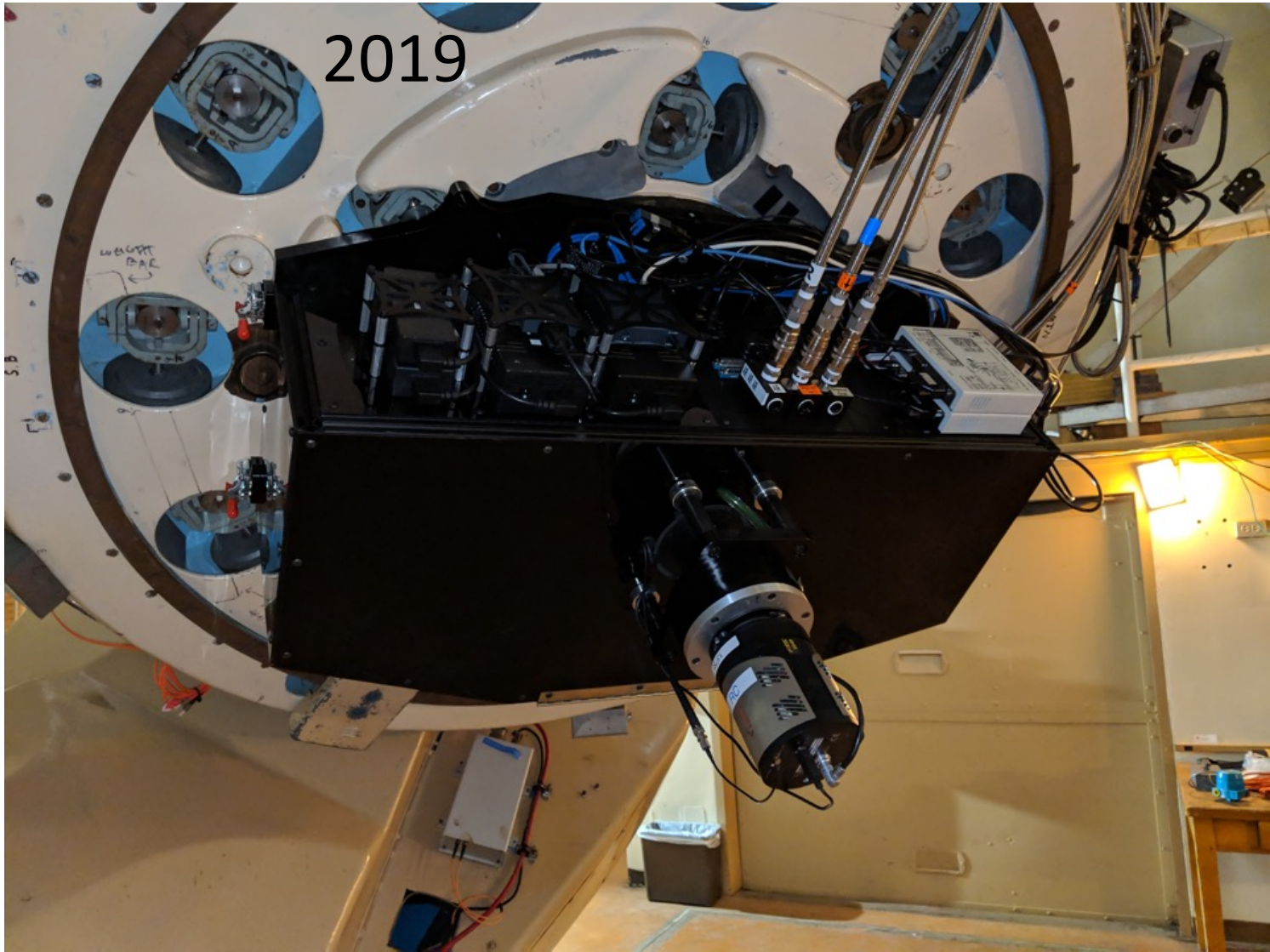



**New MLA: 2018 July 03**

**Single 18.5 g mag  1600s**

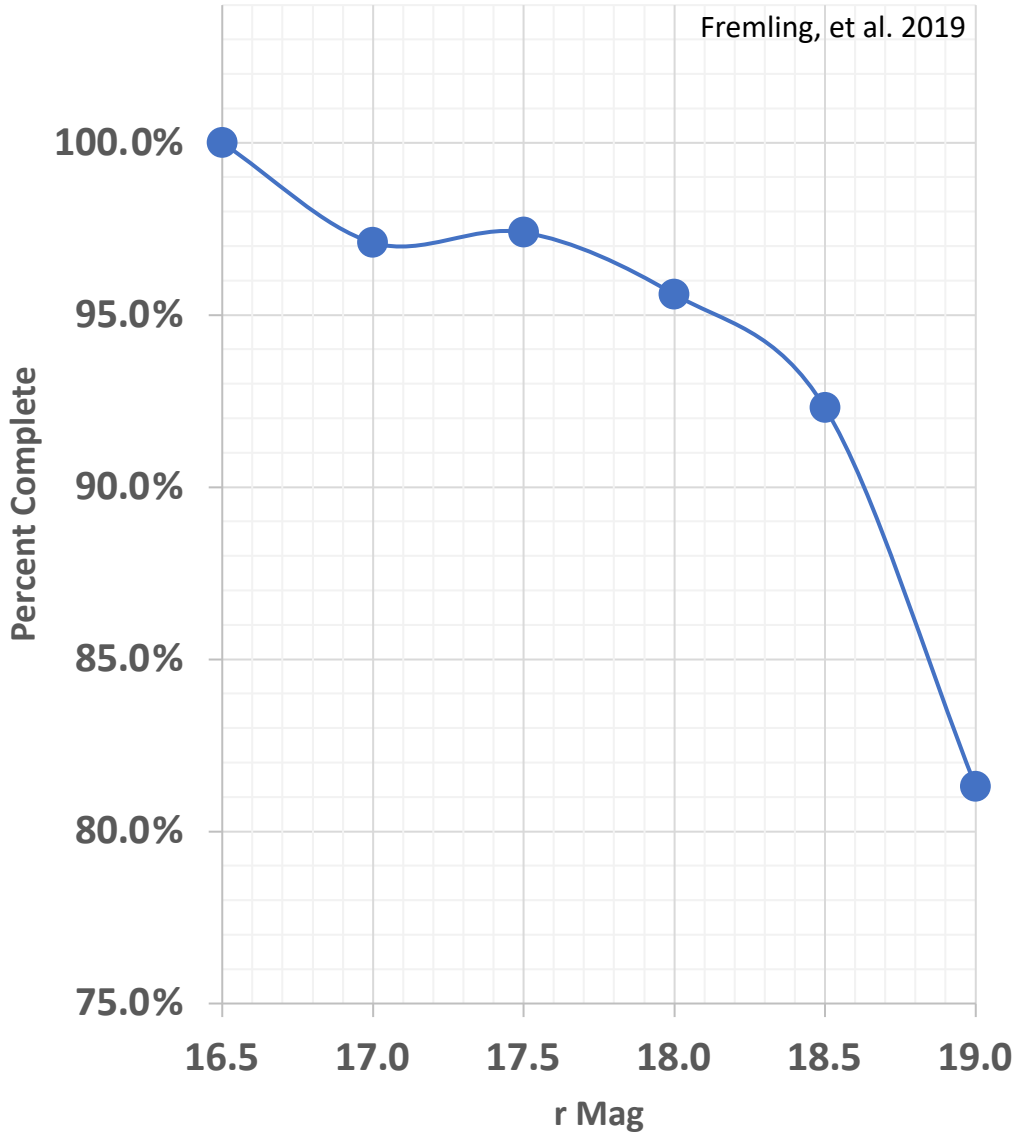


# History: Enclosure, Electronics, Re-design

# SEDM Accomplishments (as of 10-14-2022)

- ***Leading classifier of SNe on TNS website***
  - 4315 having SEDM as official classifier, 46% since ZTF start
  - Since ZTF start a factor of 4 times next instrument
  - 4620 total classifications including supporting and non-SN
- Averages 11 spectra every night
  - Averaged over all nights including cloudy and engineering
- Averages 8 ZTF spectra every night
  - SN spectral completeness @ r <= 18.5 > 90%
- Fast response
  - GRB observation record is 525s after trigger
  - Spectrum produced 0.84h after trigger
- Automated classifications with SNIascore
  - 981 TNS SNe Ia with SNIascore > 0.9

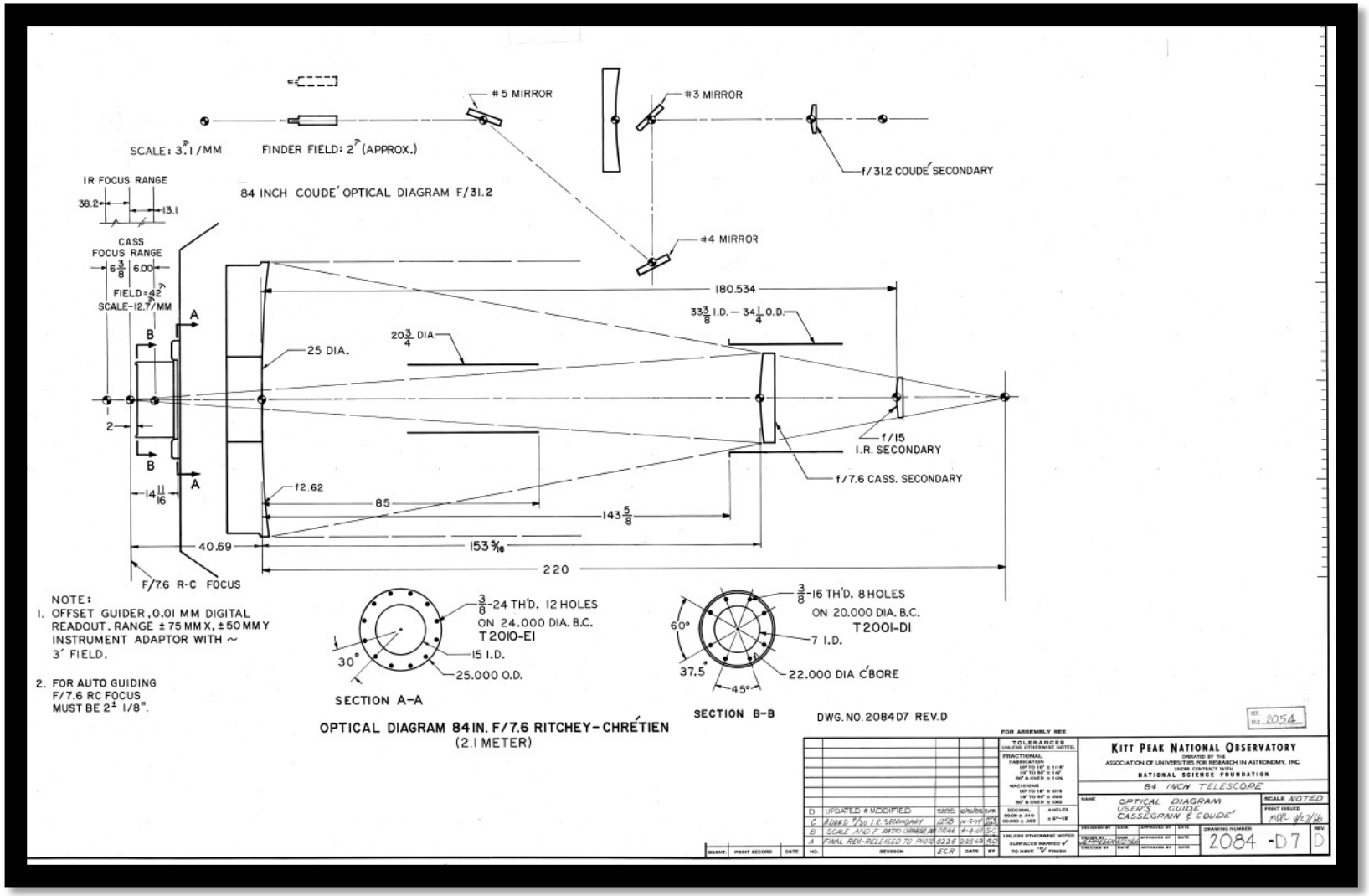


# Big Picture
*“no mean plans”*

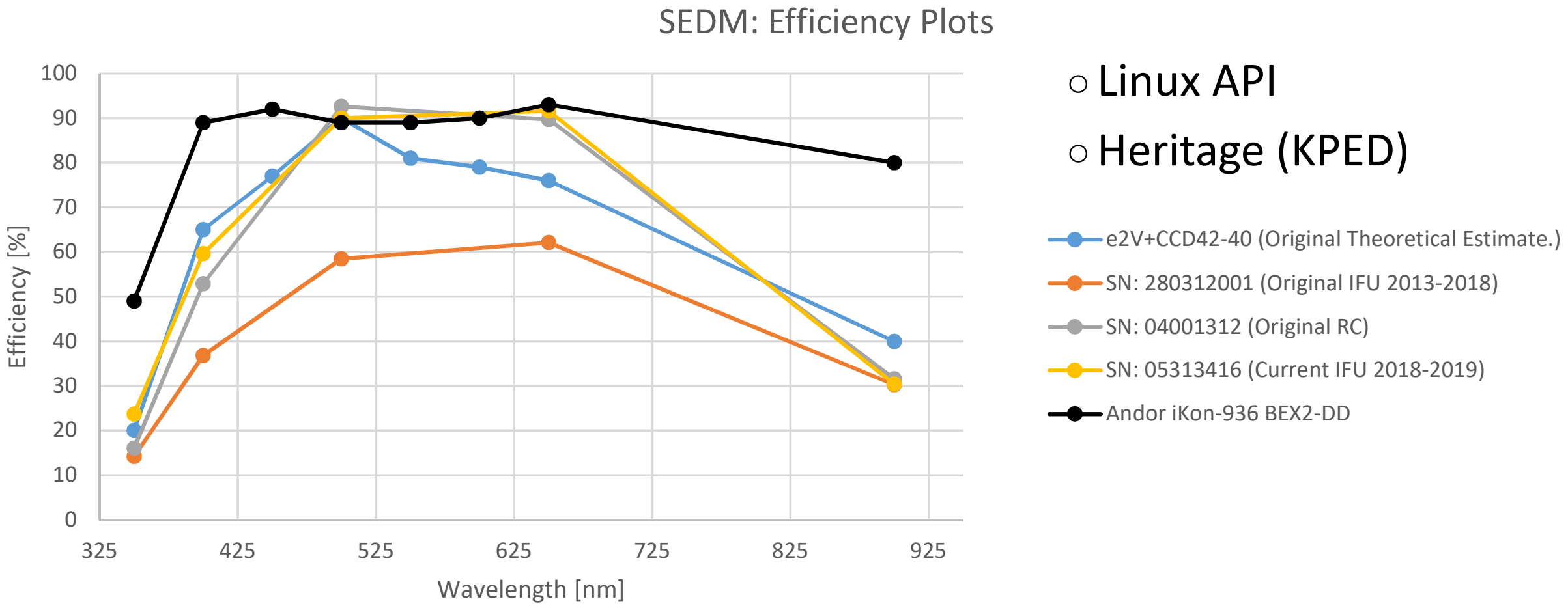
- **World domination!**
- Robotic follow-up for ZTF-II, LSST, all time-domain!
- With KP2.1m+ could achieve 90%+ completeness down to 19+ mag
- Win by focusing on classification:
  - Low resolution -> high throughput -> many classifications
- Infrastructure and coordination are important: Web/DB
- Future SEDMs: southern/eastern hemispheres?

# Kitt Peak 2.1m: Facility

- Specifications:
  - Primary: 2.1m (84in)
  - 2x P60 area = +0.75mag
  - Secondary: f/7.6
  - Automated for KPED
- Caltech History:
  - 3yrs with RoboAO
  - 4yrs with KPED

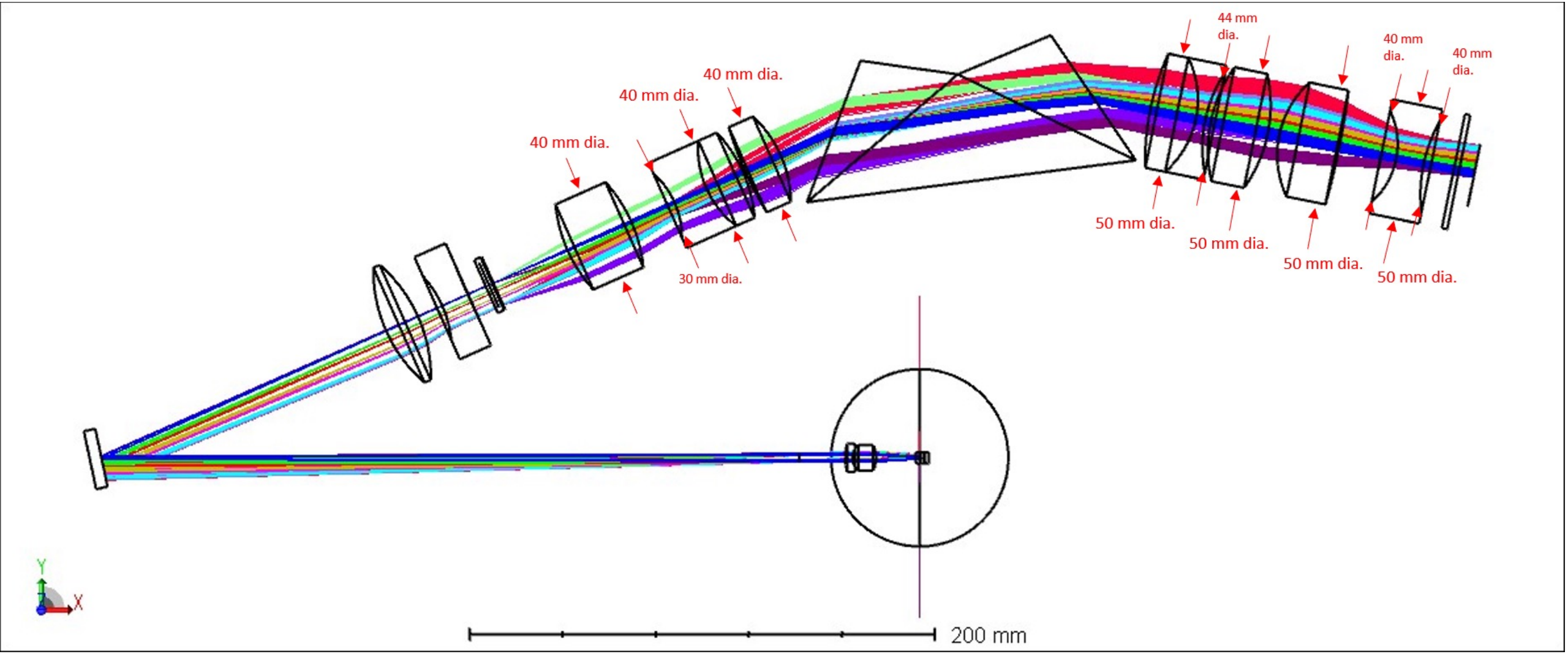


# Improve Throughput in Blue & Red: Andor iKon

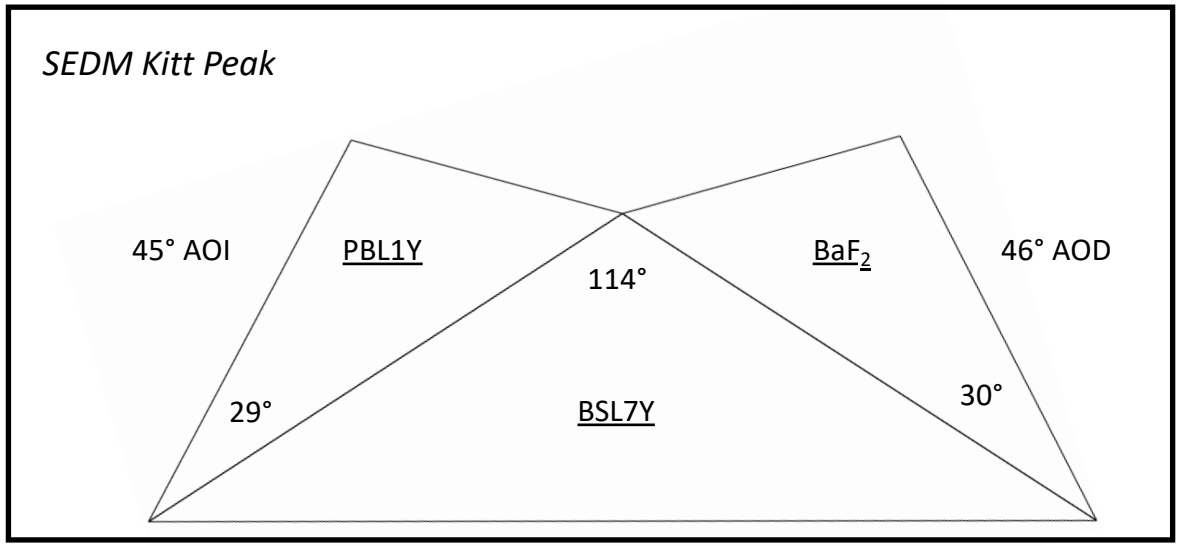


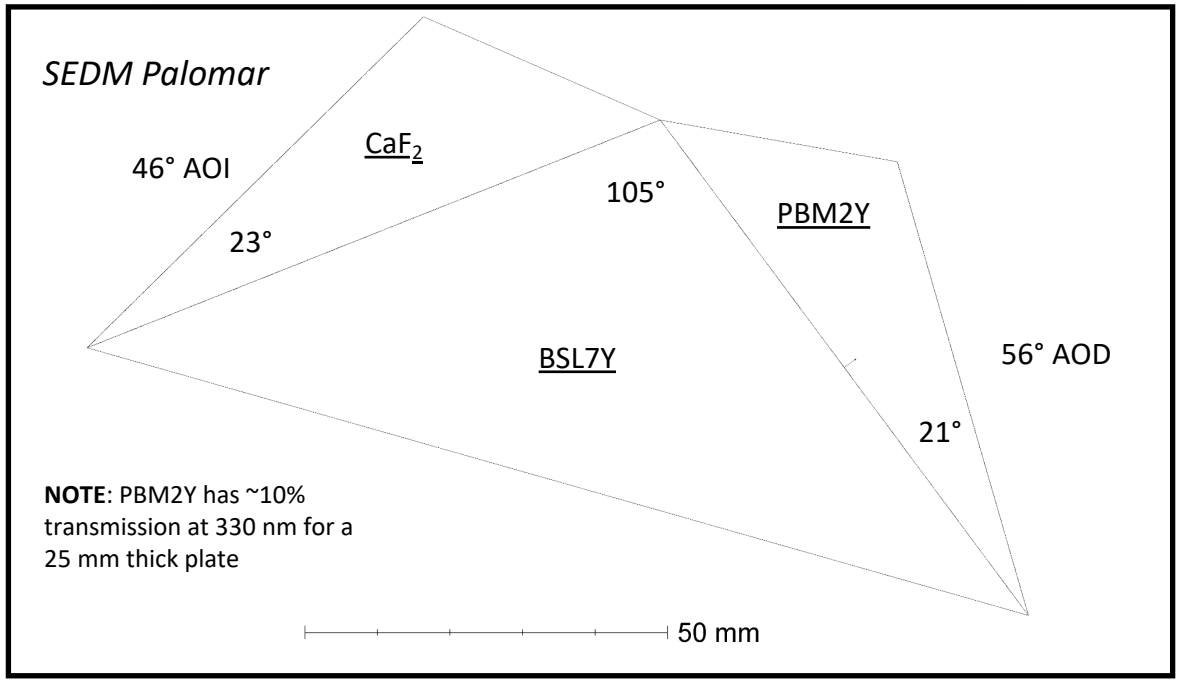

- Linux API
- Heritage (KPED)

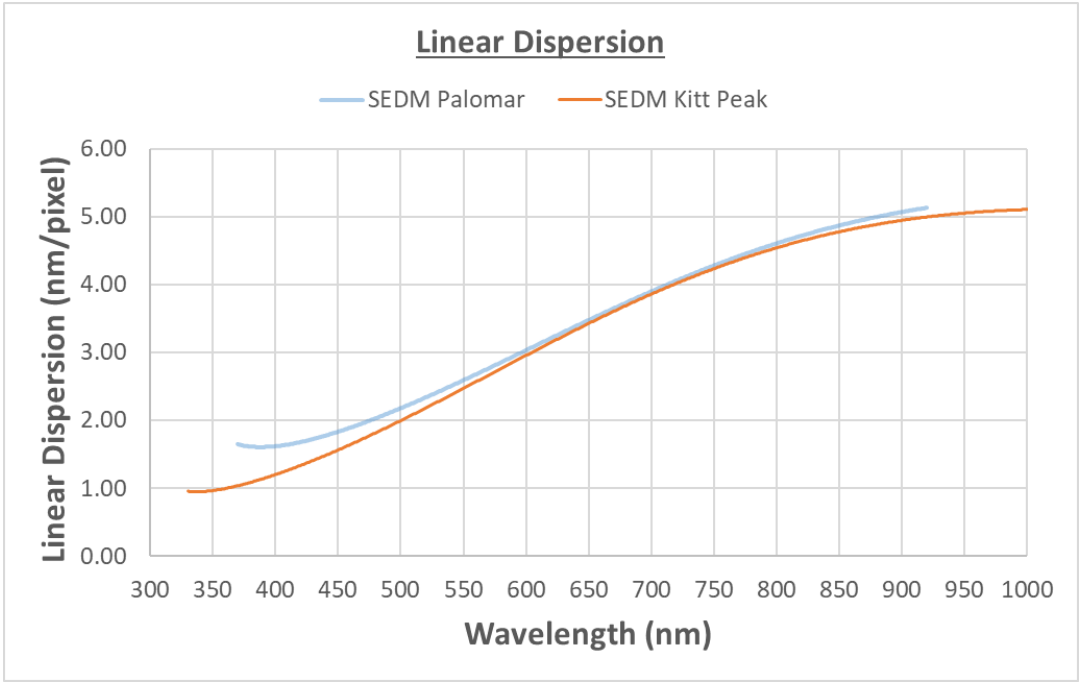
# Refine Optical Design

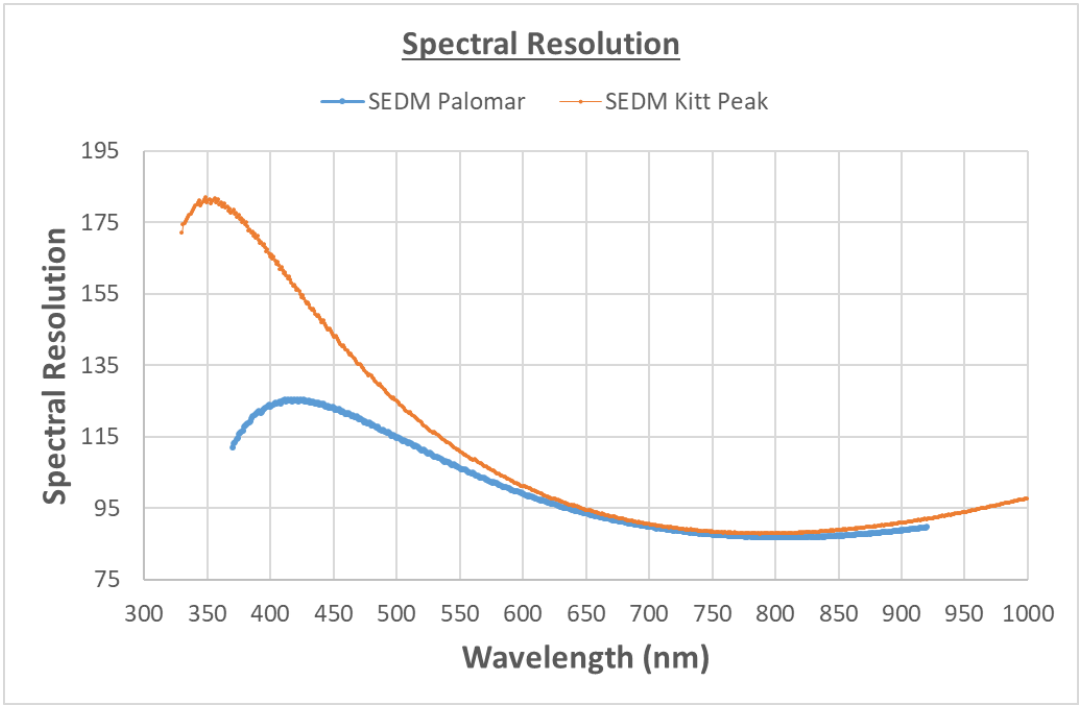


# Prism Dispersing Element Design



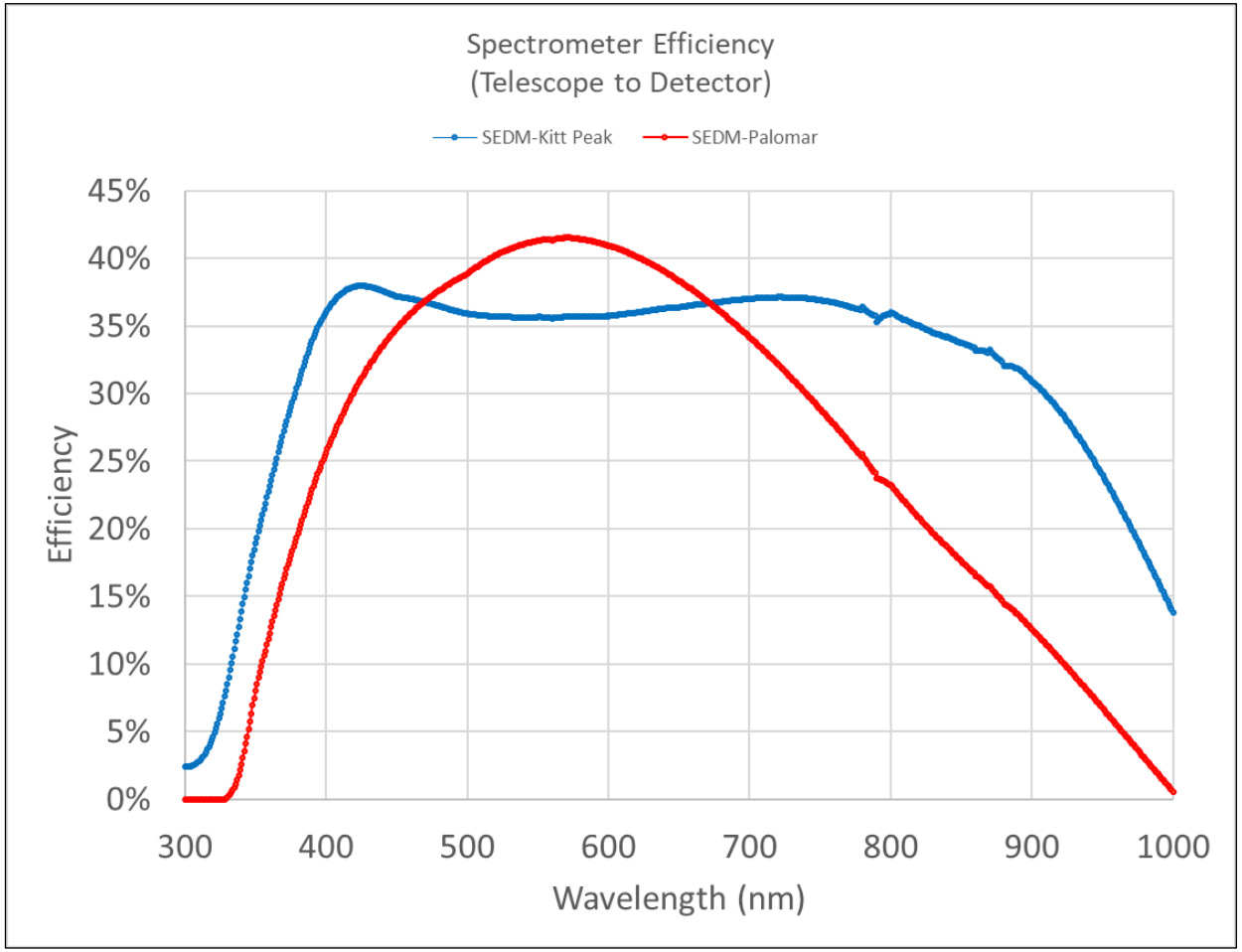



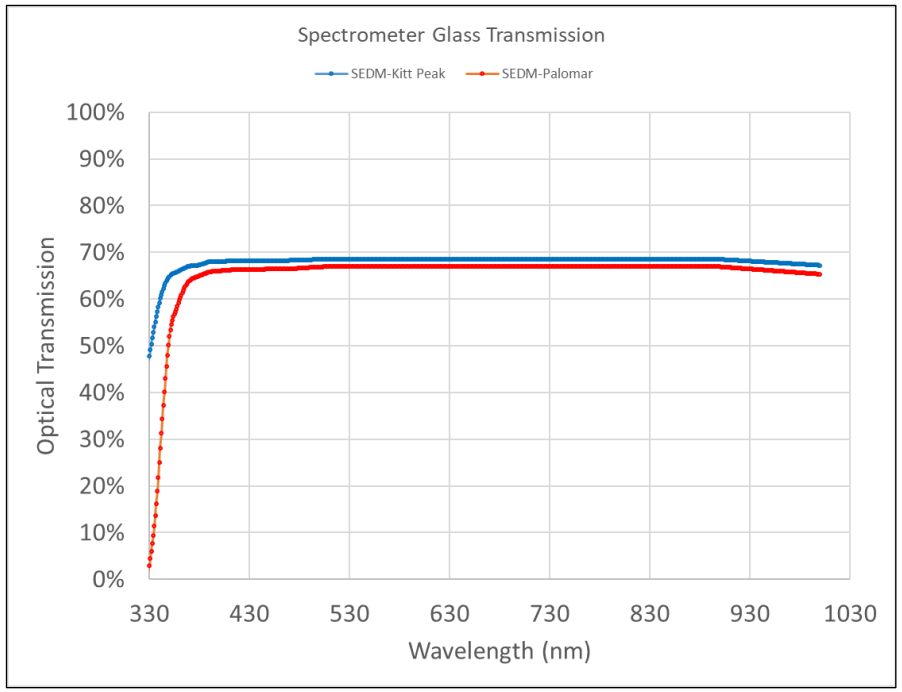



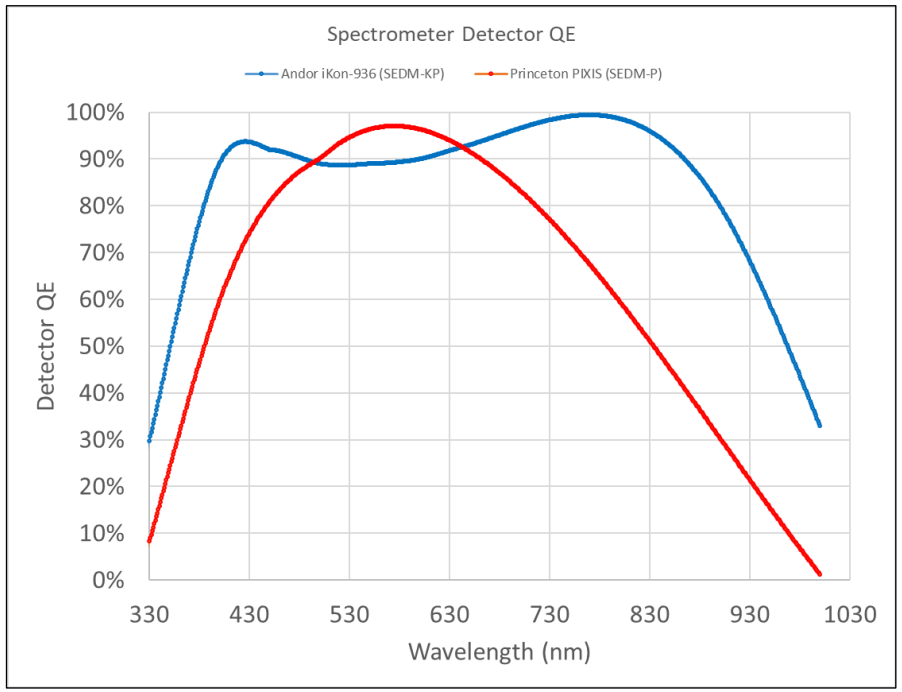



# Optical Transmission and Instrument Efficiency

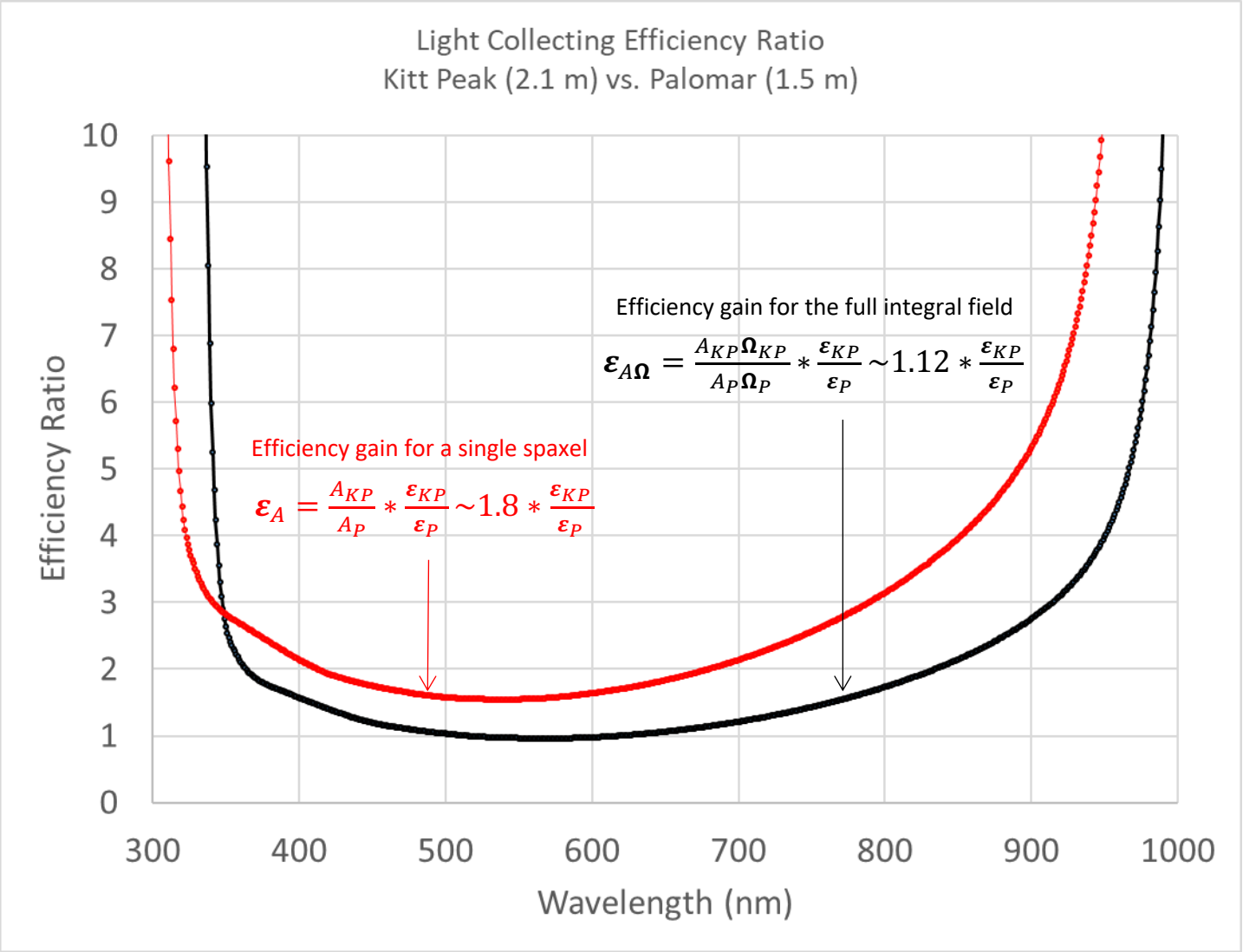
-- Kitt Peak central obstruction is ~40% (by diameter) yielding an integrated light loss of 16%.
-- Palomar central obstruction is ~25% (by diameter) yielding an integrated light loss of 8%.
-- Blacked out transition zones in MLA yield ~6% loss (measured in lab).
-- MLA aperture losses yield ~10% loss (measured in lab).
-- Assume 1% loss per optical surface (Fresnel losses)
-- Assume Aluminum reflective coating on telescope mirrors.



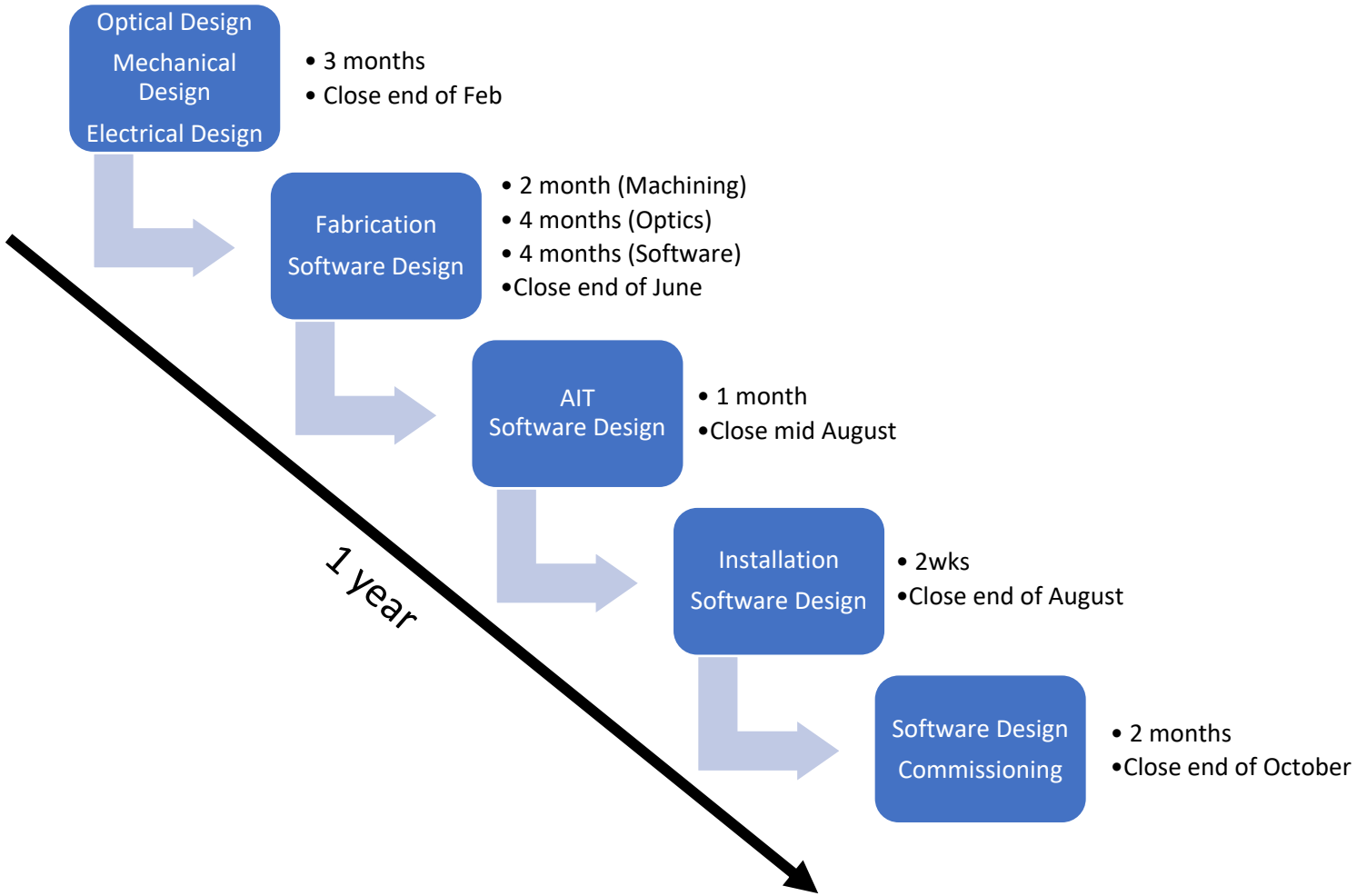



# Light Collecting at SEDM-KP relative to SEDM-P




-- A is the area of the primary mirror (including central obscuration), $\boldsymbol{\Omega}$ is the solid angle on-sky, and $\boldsymbol{\varepsilon}$ is the spectrometer efficiency (telescope to detector).
-- Larger aperture (1.8x factor), but smaller FOV (0.62x factor) when at Kitt Peak.
-- Mid-band (500 nm to 700 nm) gains come from larger aperture telescope, Blue-band (330 nm to 500 nm) and Red-band (700 nm to 1000 nm) gains come from glass and detector choices.

# Design Review, Jan 2020: Initial Schedule



# History: Setbacks

- Partial funds identified
- Estimated commissioning in Oct. 2020!
- KP2.1m lease up in 2020
- Waiting for telescope proposal call
  - Hard to raise funds for instrument without telescope secured
- Pandemic hits in March of 2020!

# History: Christmas Present

- Dec 23, 2020: KP extends Caltech lease of KP2.1m to 2025!
- Fundraising  begins in earnest
- March 2021: first outside funds allow design/fab work to begin

# Fabrication During a Pandemic

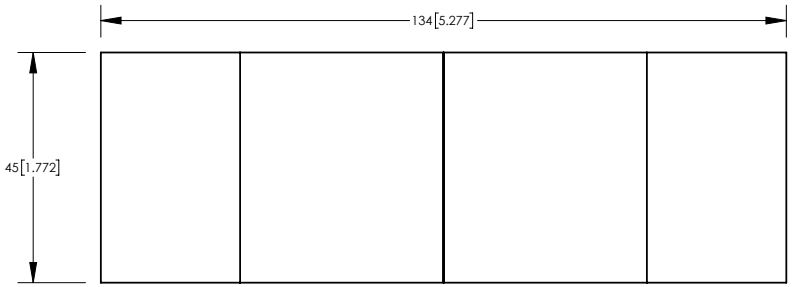
- Extended all vendor timelines
  - Outsourced optics and mountings
- Supply-chain issues
  - Tri-prism glasses re-designed
  - COTS fused silica single prism stop-gap

# Prism Re-design

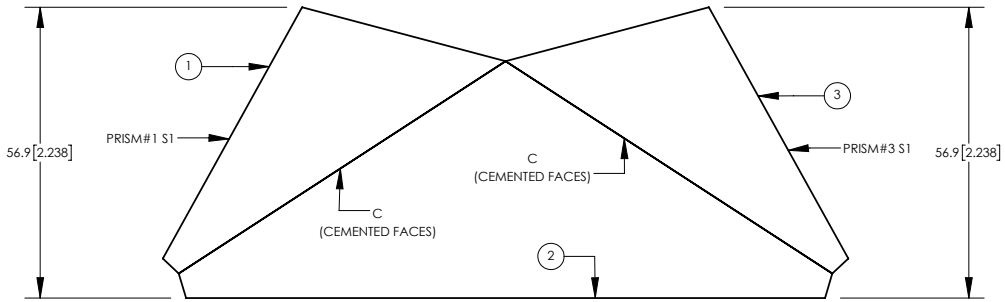
Notes: Unless otherwise DETAILED

1. Based on optical prescription *20210802G-1_SEDMKP_SPECTRO*
2. **All dimensions are specified for a lab ambient temperature of 20˚C**
3. Operating temperature range is 8°C ±10°C
4. Prism faces marked with "C" are cemented with Norland Optical Adhesive NOA88 with a nominal bond line thickness of 0.015 mm (or Sylgard 184 with a nominal bond line thickness of 0.040 mm)
5. Shipping container shall not contact any coated optical surfaces.
6. Prism assembly will be shipped in a protective hard case.

| REVISIONS | | |
|---|---|---|
| REV. | ZONE | DESCRIPTION |
| 0 | | INITIAL RELEASE |
| A | | NO CHANGE TO ASSY; UPDATED PRESCRIPTION REFERENCE |




**SCALE 1 : 1**




**SCALE 1 : 1**

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY |
|---|---|---|---|
| 1 | SEDMKP-OPT-P0029 | PRISM 1 (PBL1Y) | 1 |
| 2 | SEDMKP-OPT-P0028 | PRISM 2 (BSL7Y) | 1 |
| 3 | SEDMKP-OPT-P0030 | PRISM 3 (S-FSL5Y) | 1 |

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN mm [in] *([in] DIMS FOR REFERENCE ONLY)*
MACHINED FILLET RADII: R0.4-0.7 [0.015-0.03]
DE-BURR/BREAK EDGES: 0.2-0.7 [0.008-0.03]RADIUS OR CHAMFER
MACHINED SURFACE ROUGHNES: µm Ra 1.6 0.8 | µin Ra 63 0.03

GENERAL TOLERANCES

| LINEAR | | | |
|---|---|---|---|
| 0 - 6 | ±0.1 | [0 - 0.24] | [±0.004] |
| >6 - 30 | ±0.2 | [>0.24 - 1.2] | [±0.008] |
| >30 - 120 | ±0.3 | [>1.2 - 4.7] | [±0.012] |
| >120 - 315 | ±0.5 | [>4.7 - 12.4] | [±0.020] |
| >315 - 1000 | ±0.8 | [>12.4 - 39.4] | [±0.031] |
| >1000 | ±1.2 | [>39.4] | [±0.047] |

ANGULAR: MACHINED: ±0.5° BENT: ±1.0°

MATERIAL

| | | |
|---|---|---|
| CREATED | J. Fucik | |
| EDITED | J. Fucik | |
| ENG APPR. | | |
| RELEASED | | |

INTERPRET DRAWING IN ACCORDANCE WITH ASME Y14.100
GEOMETRIC TOLERANCING PER ASME Y14.5M-2009

**DO NOT SCALE DRAWING**

THIRD ANGLE PROJECTION

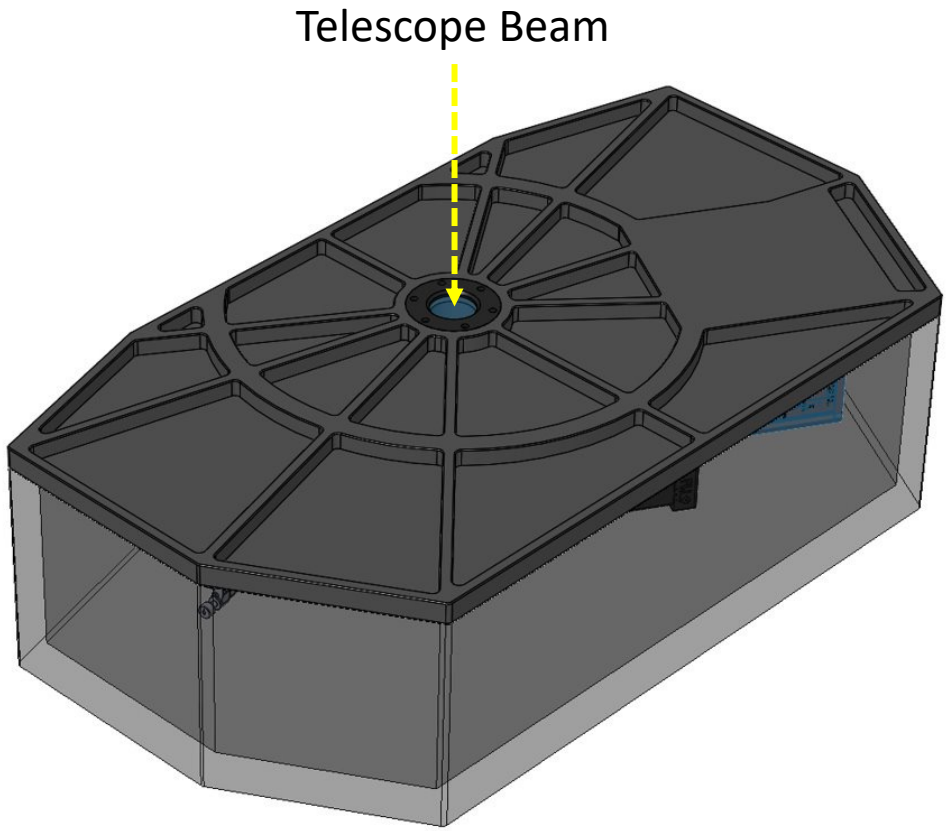
**CALIFORNIA INSTITUTE OF TECHNOLOGY**
CALTECH OPTICAL OBSERVATORIES

TITLE:
TRI-PRISM ASSEMBLY
SEDM-KP PROJECT

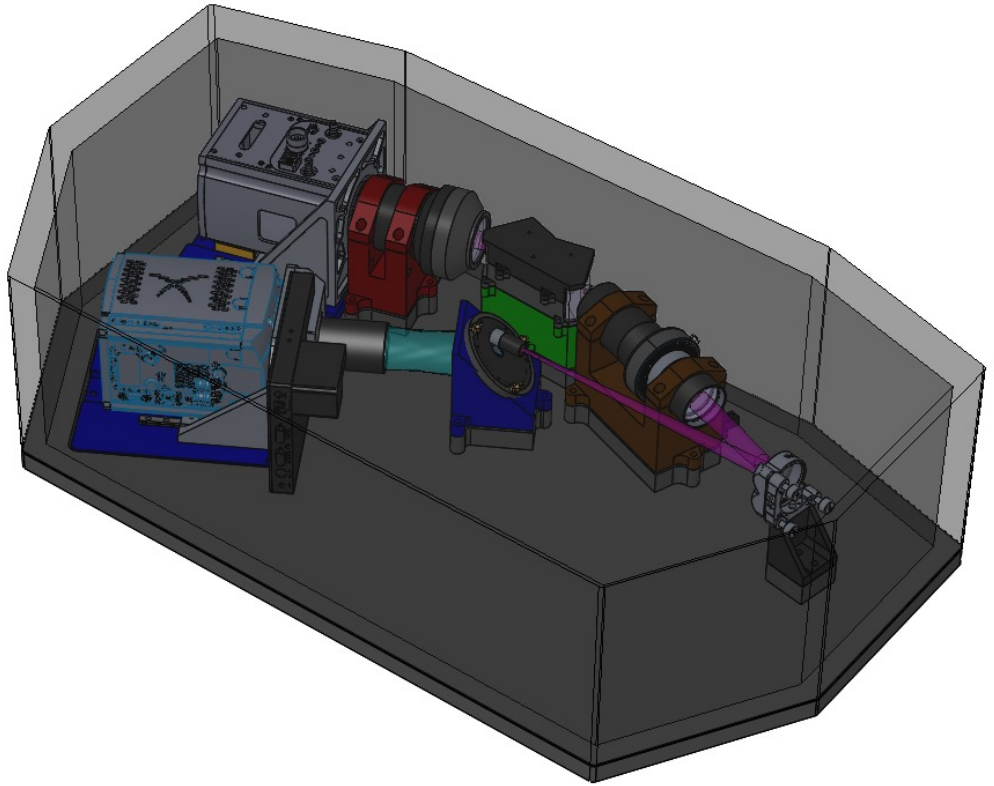
| SIZE | DWG. NO. | REV |
|---|---|---|
| B | SEDMKP-OPT-A0004 | A |
| SCALE: 1:5 | WT: kg | SHEET 1 OF 1 |

REV A
DRW. NO. SEDMKP-OPT-A0004

# SEDM-KP: [Instrument Overview]

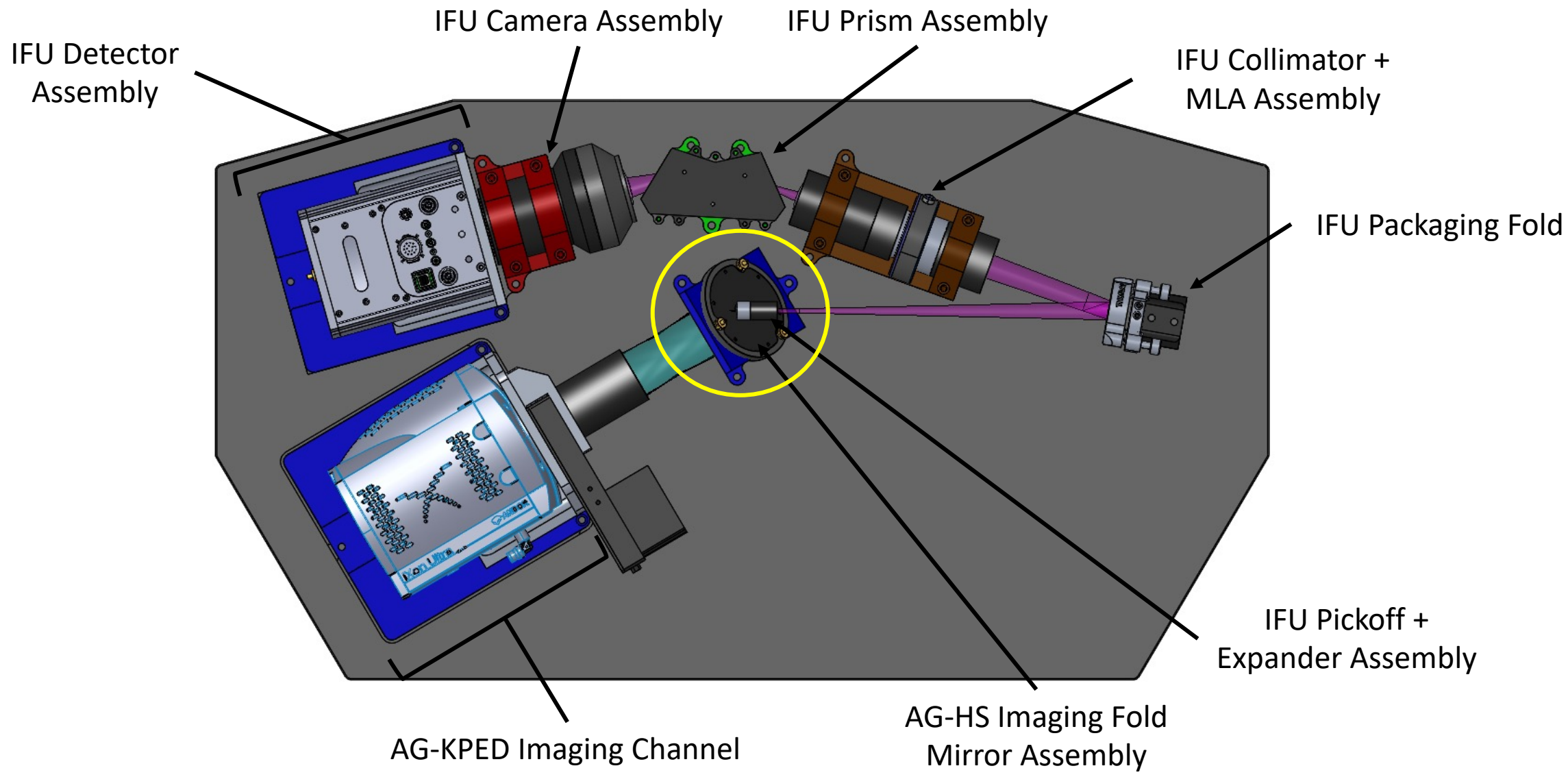



Telescope Orientation

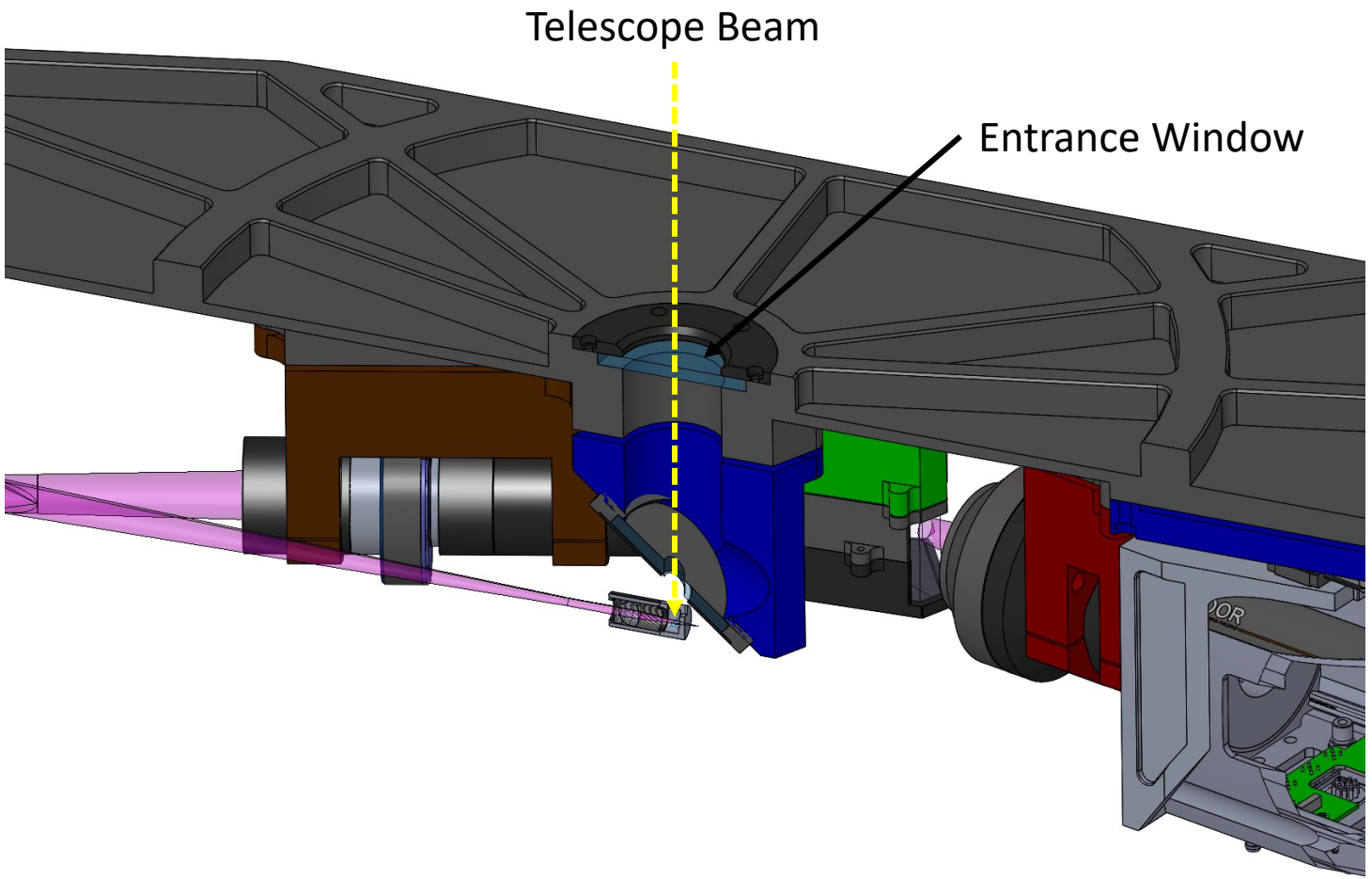


AIT Orientation

# SEDM-KP: [Instrument Overview]

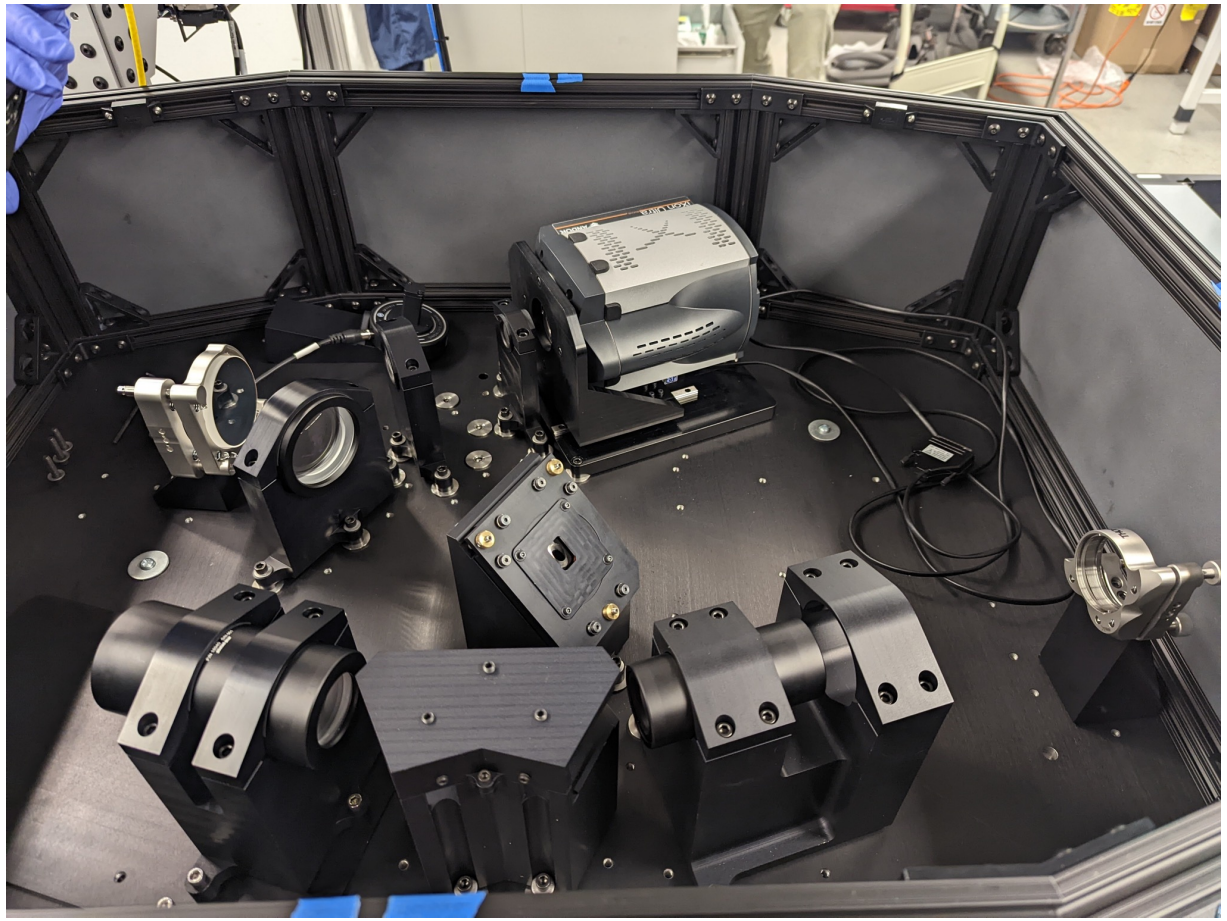


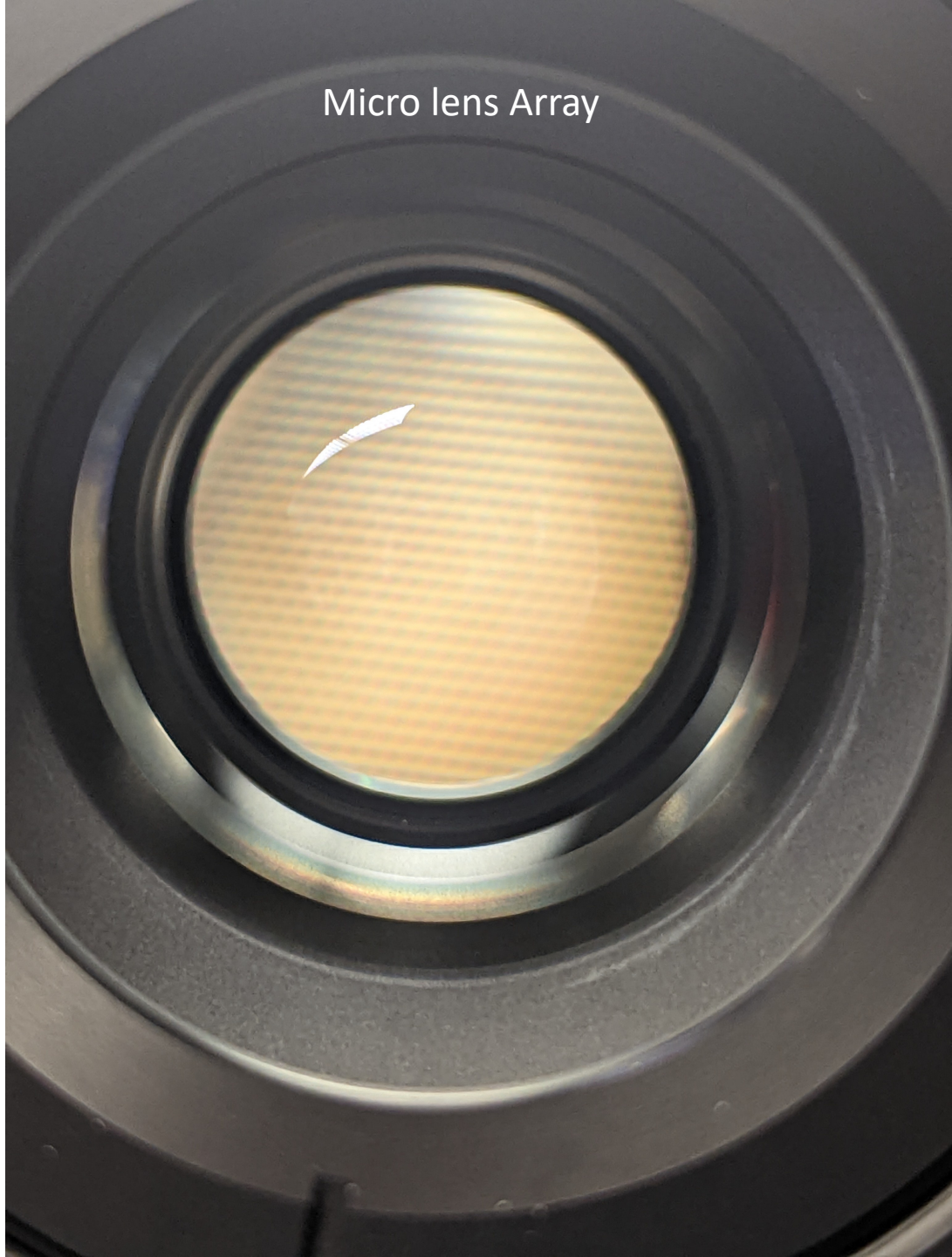
# SEDM-KP: [IFU Pickoff, AG-KPED Fold Mirror + Expander Assembly]

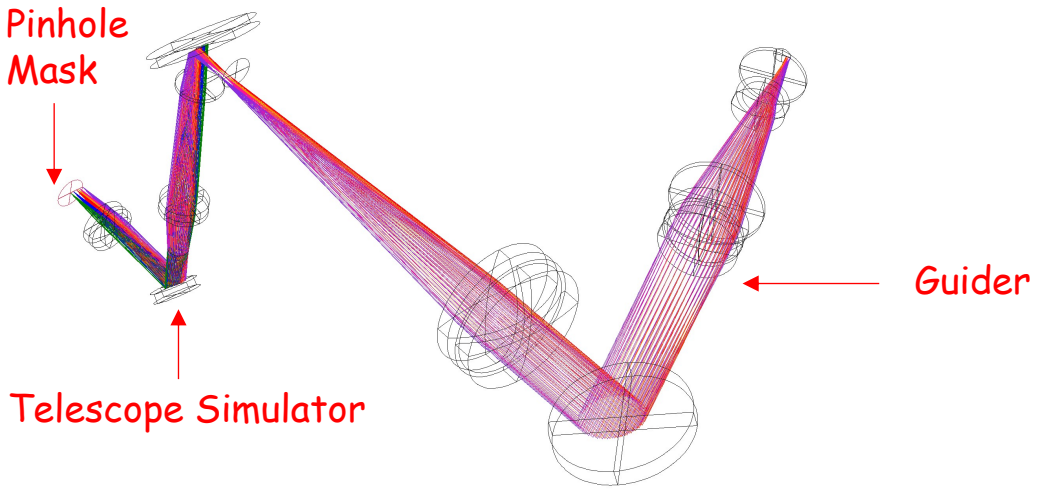


# Fabrication During a Pandemic

# Fine Alignment

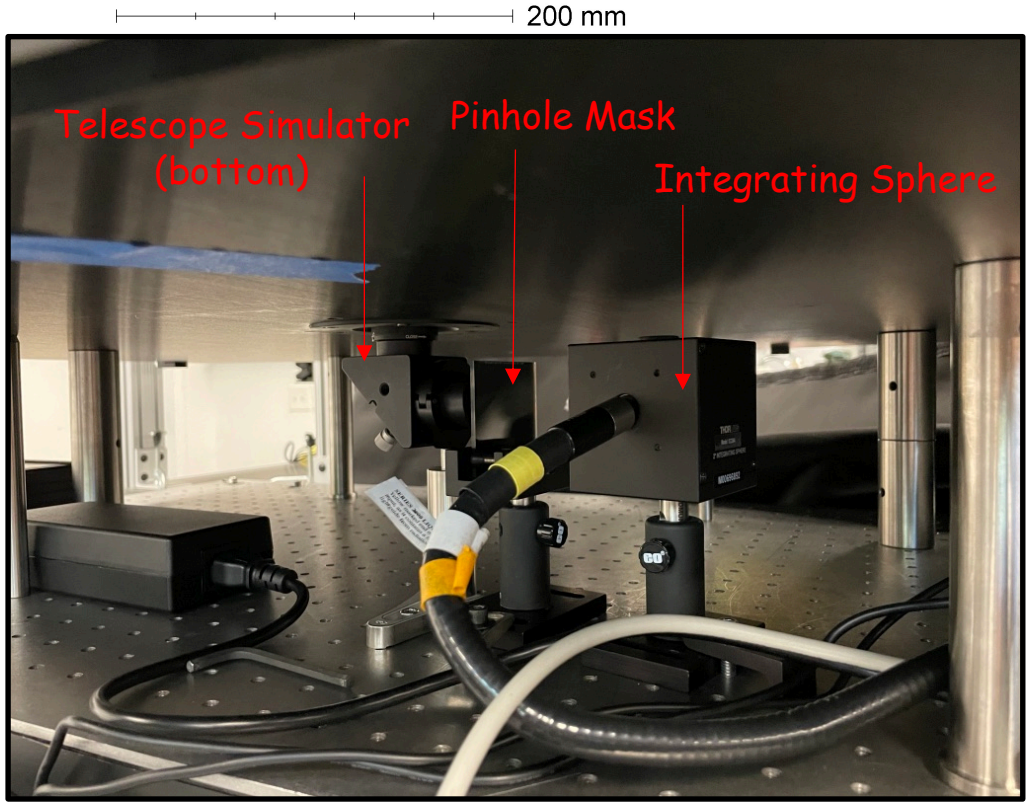


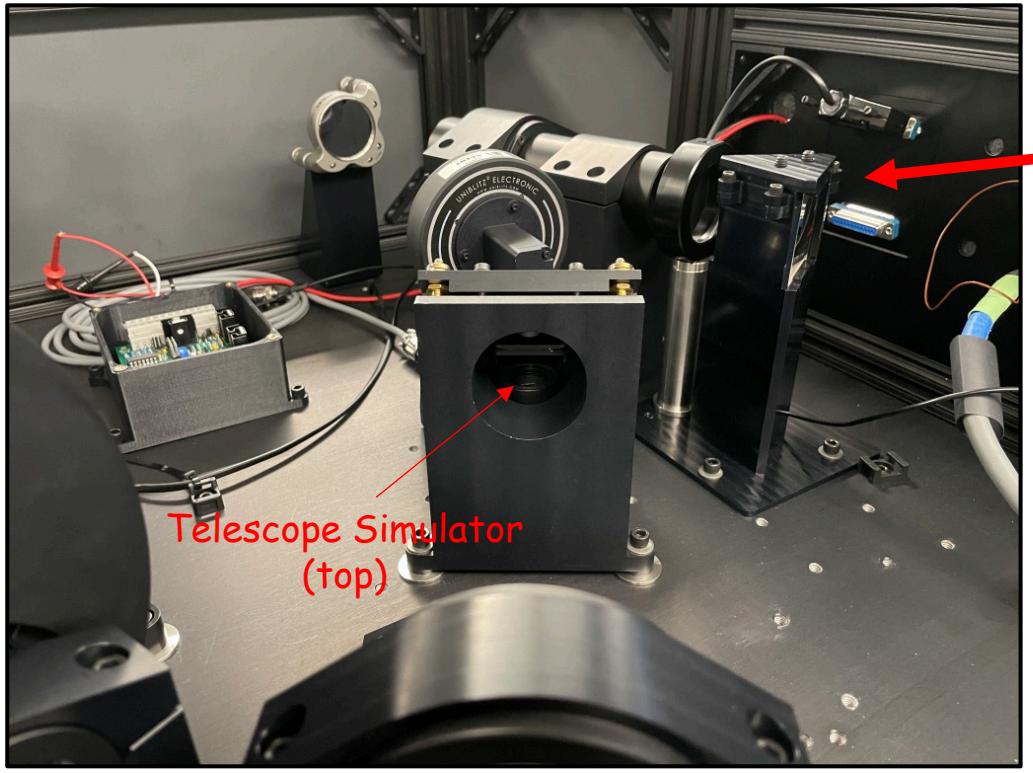





# Telescope Simulator Installed

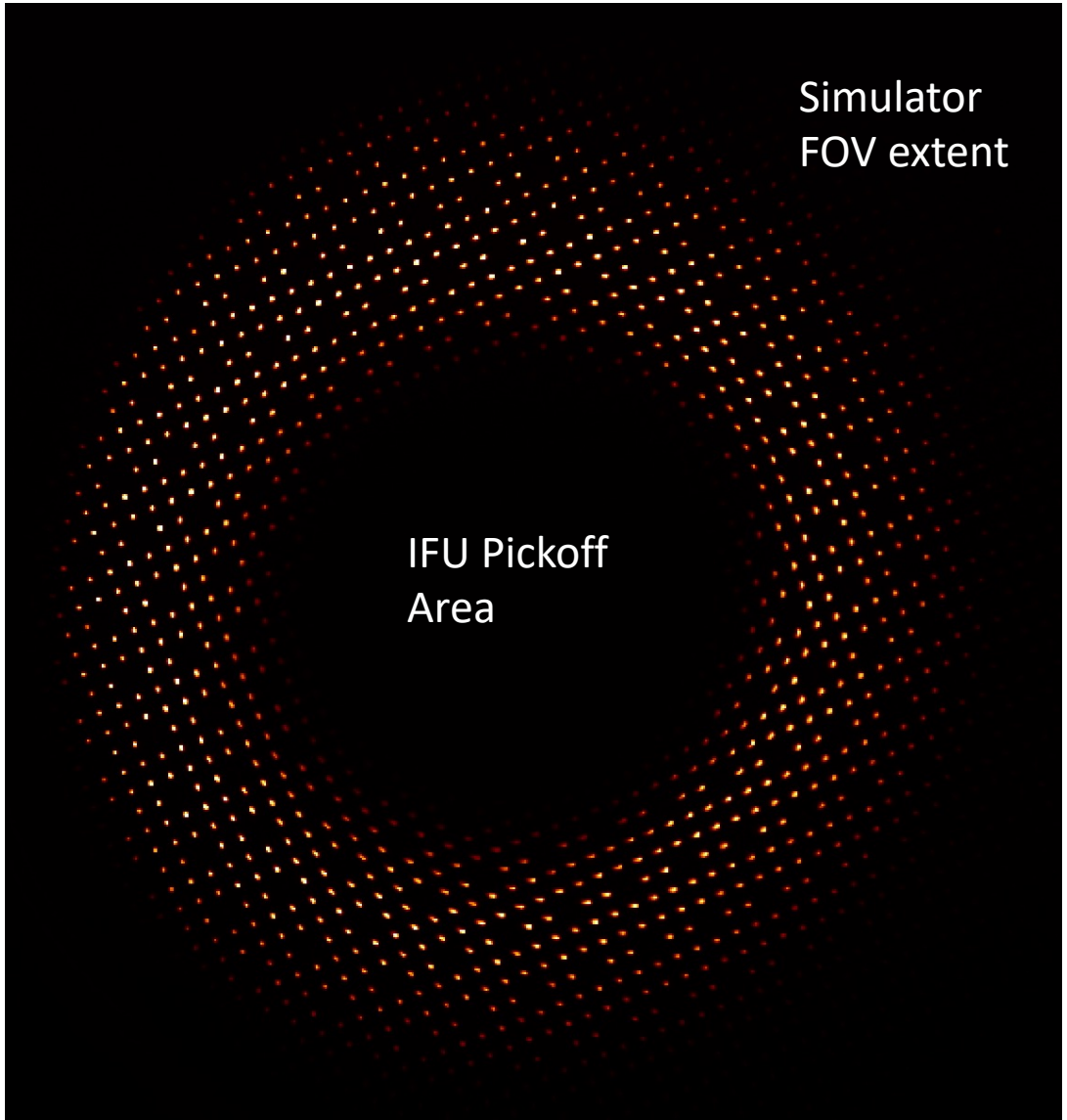
Thanks to UMinn!

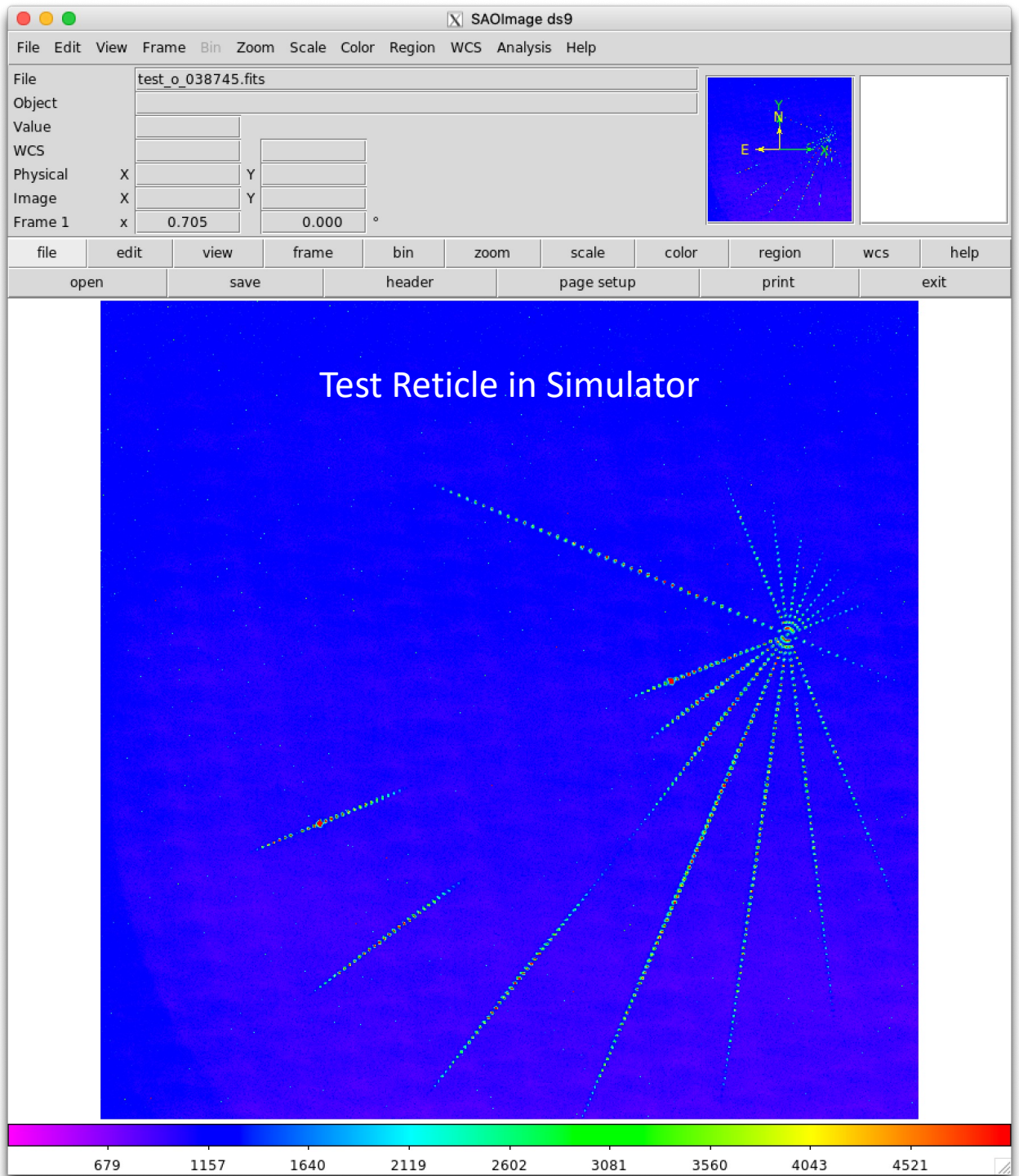


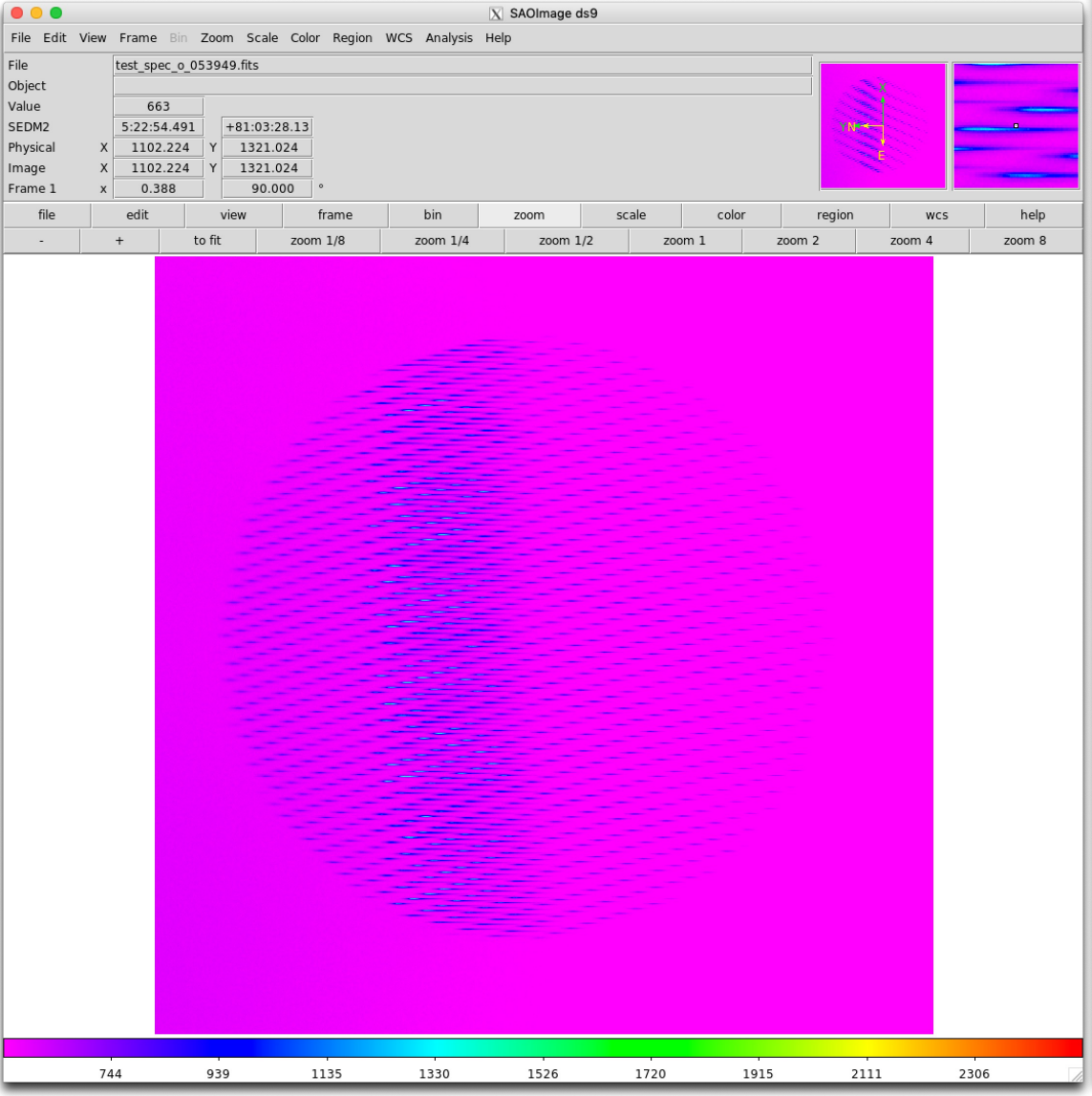

Fused Silica
Equilateral
Prism
(Temporary)

# Guider Aligned



# IFU Aligned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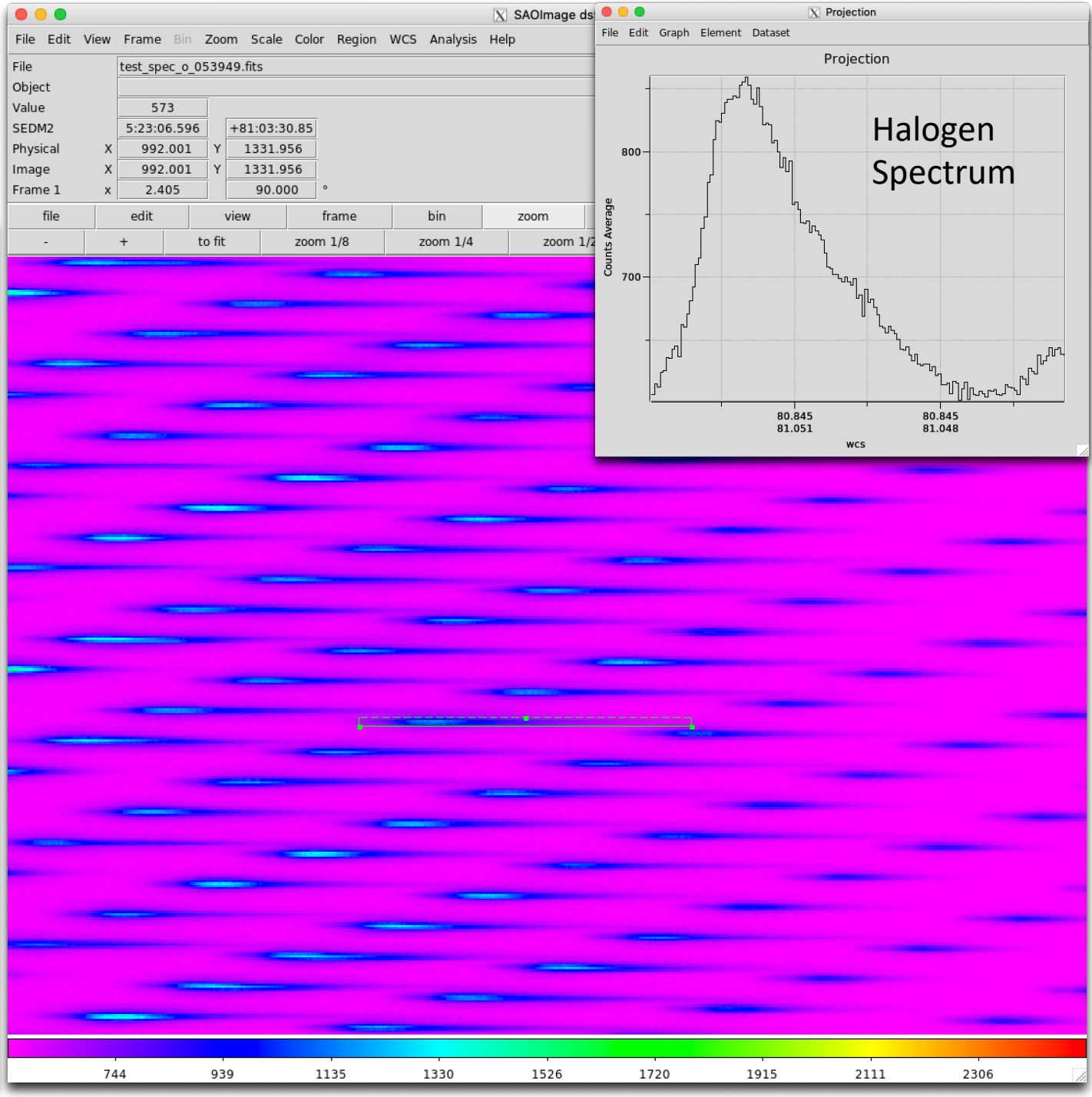
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File test_spec_o_053949.fits
Object
Value 663
SEDM2 5:22:54.491 +81:03:28.13
Physical X 1102.224 Y 1321.024
Image X 1102.224 Y 1321.024
Frame 1 x 0.388 90.000 °
file edit view frame bin zoom scale color region wcs help
- + to fit zoom 1/8 zoom 1/4 zoom 1/2 zoom 1 zoom 2 zoom 4 zoom 8
744 939 1135 1330 1526 1720 1915 2111 2306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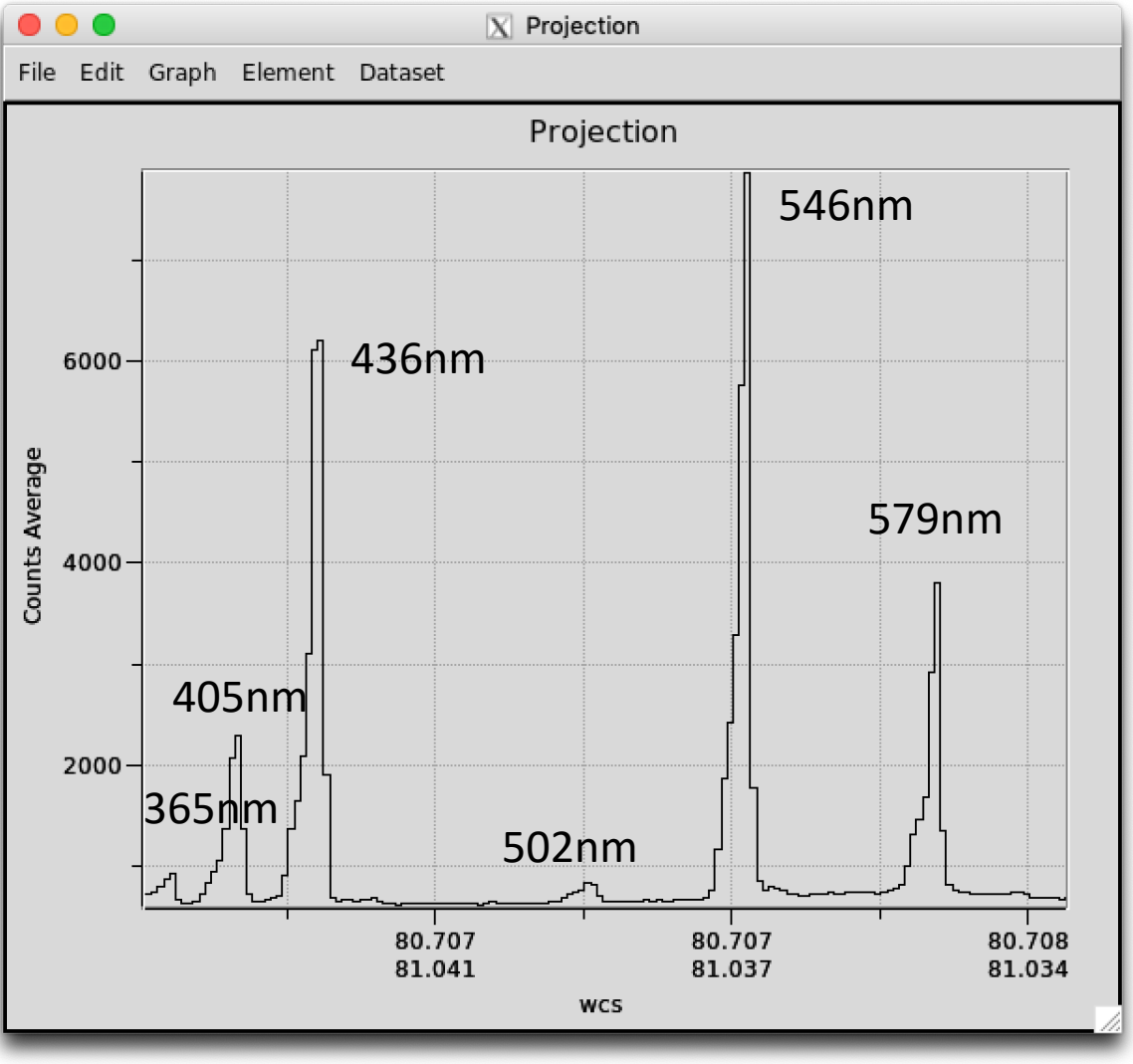
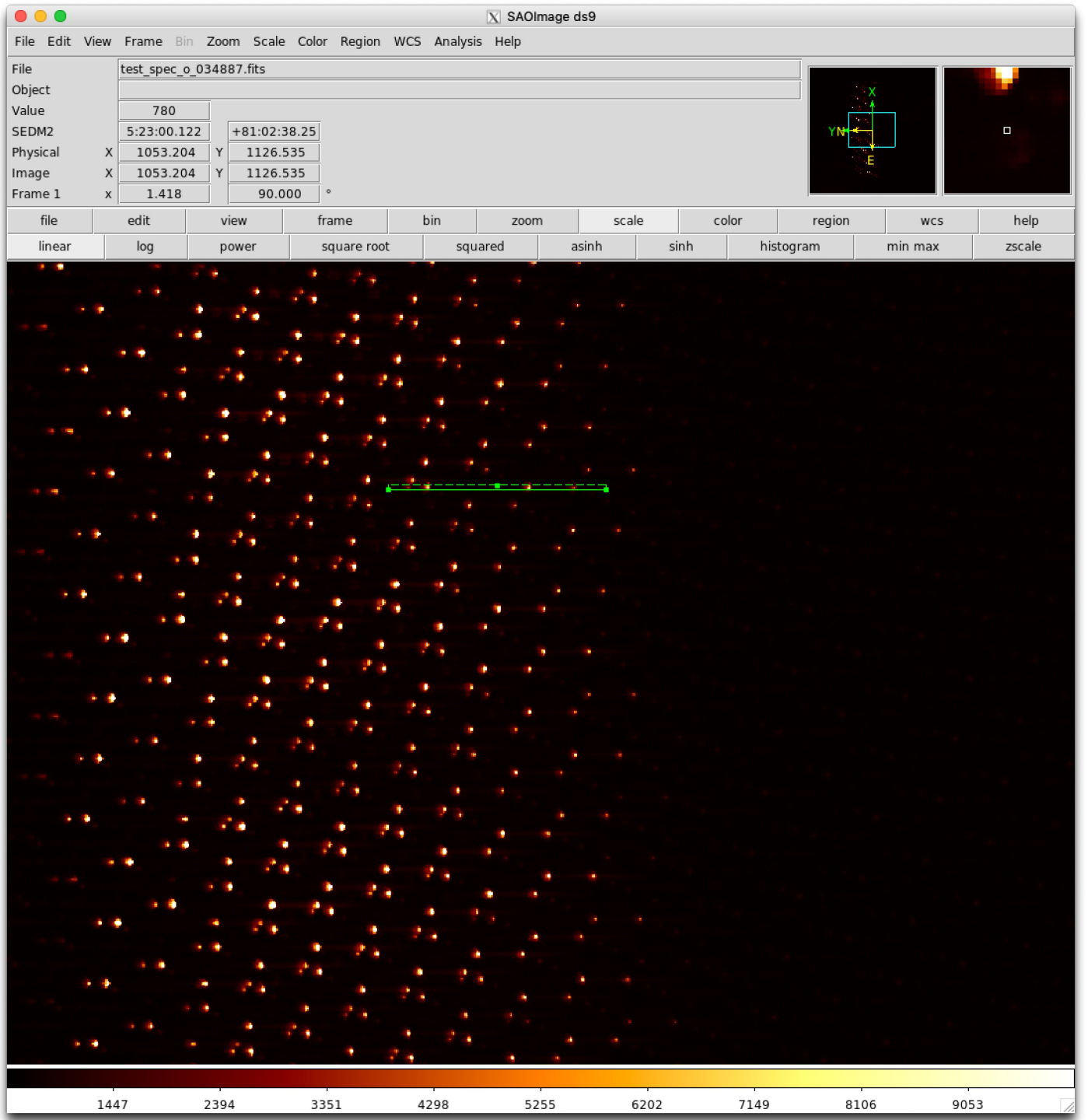
Physical X 992.001 Y 1331.956
Image X 992.001 Y 1331.956
Frame 1 x 2.405 90.000 °
file edit view frame bin zoom
- + to fit zoom 1/8 zoom 1/4
744 939 1135 1330 1526 1720 1915 2111 2306


Projection
File Edit Graph Element Dataset
Projection
Halogen Spectrum
Counts Average
800
700
80.845
81.051
80.845
81.048
wcs

# Hg Arc Lamp


Projection
File Edit Graph Element Dataset
Projection
546nm
436nm
579nm
405nm
365nm
502nm
6000
4000
2000
Counts Average
80.707
81.041
80.707
81.037
80.708
81.034
WCS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Object
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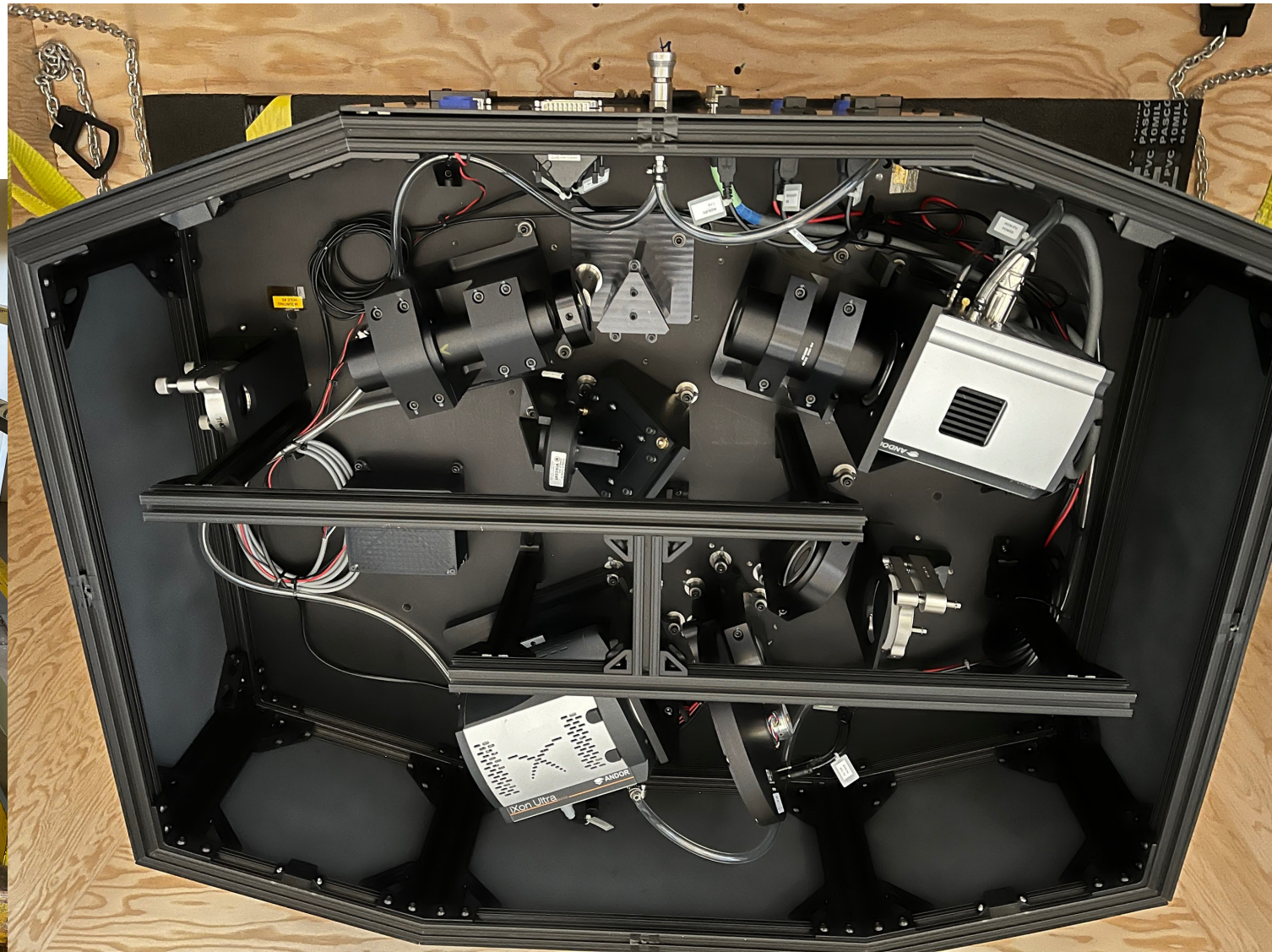
Physical X 1053.204 Y 1126.535
Image X 1053.204 Y 1126.535
Frame 1 x 1.418 90.000 °
file edit view frame bin zoom scale color region wcs help
linear log power square root squared asinh sinh histogram min max zscale
1447 2394 3351 4298 5255 6202 7149 8106 9053

# Installation before/after a Fire

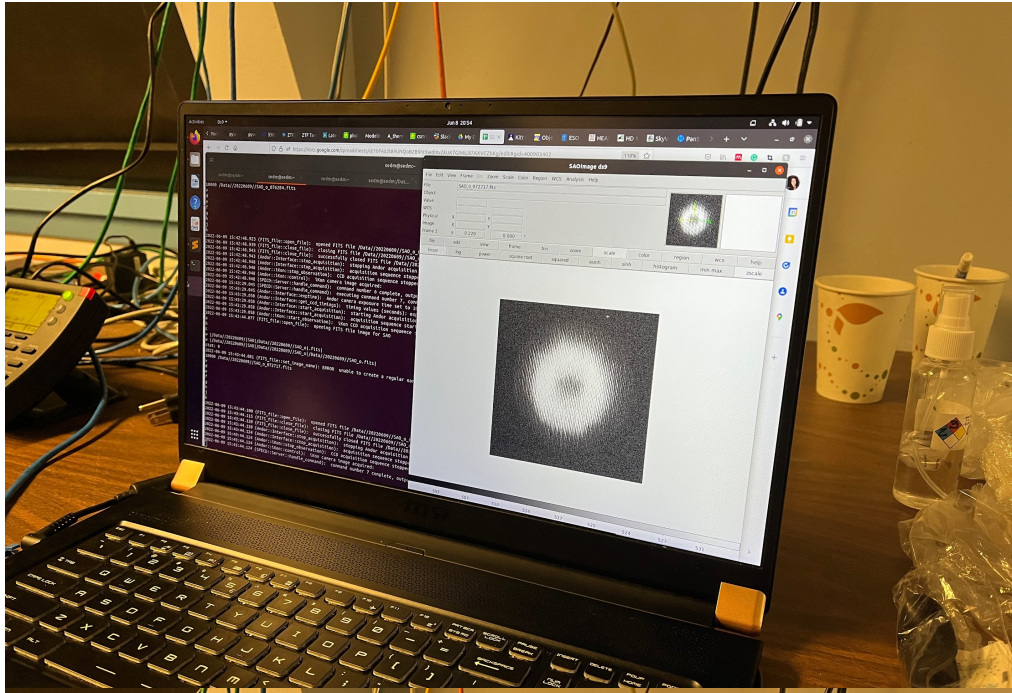
- June 5-9, 2022: Initial install with temporary prism (first light!)
- June 11, 2022: Contreras Fire starts
- June 17, 2022: 4 non-science buildings at Kitt Peak go up in flames
- June 24, 2022: Contreras Fire at 100% containment
- Sept. 19-20, 2022: Remove SEDMv2 to KP clean room for inspection/updates
- Sept. 27-28, 2022: Install tri-prism, electronics panel
- Sept. 29-30, 2022: Re-install instrument, electronics, purge coolant lines

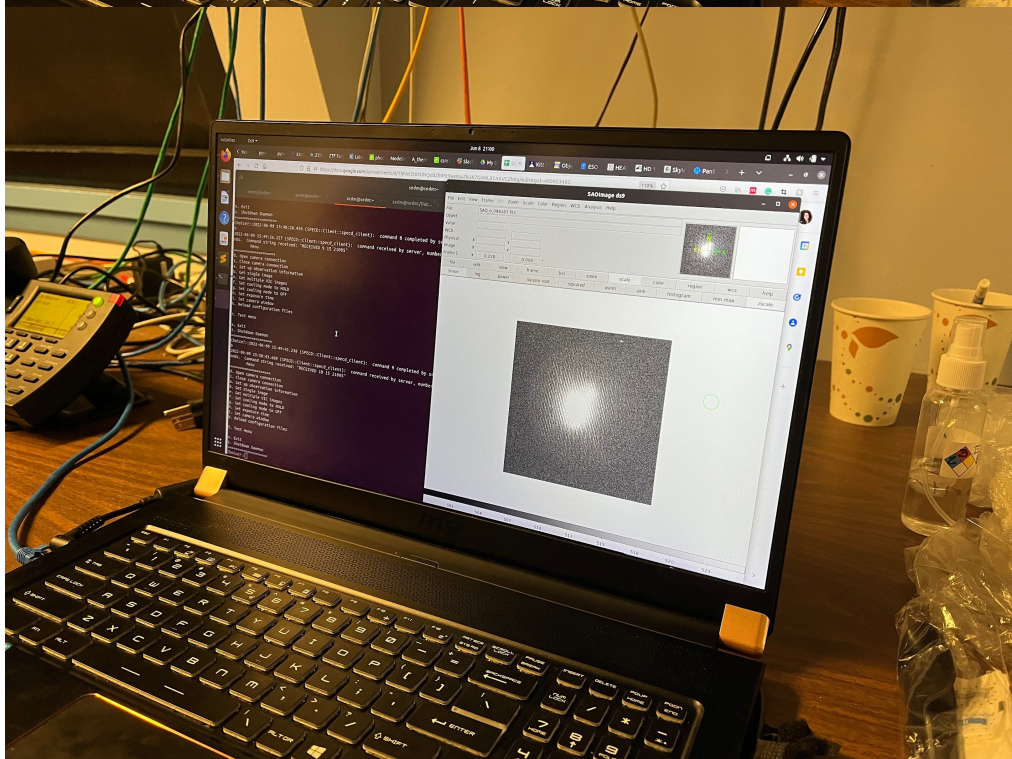
# Installation before a Fire: June 5


# Installation before a Fire: June 7



# Installation before a Fire: June 8



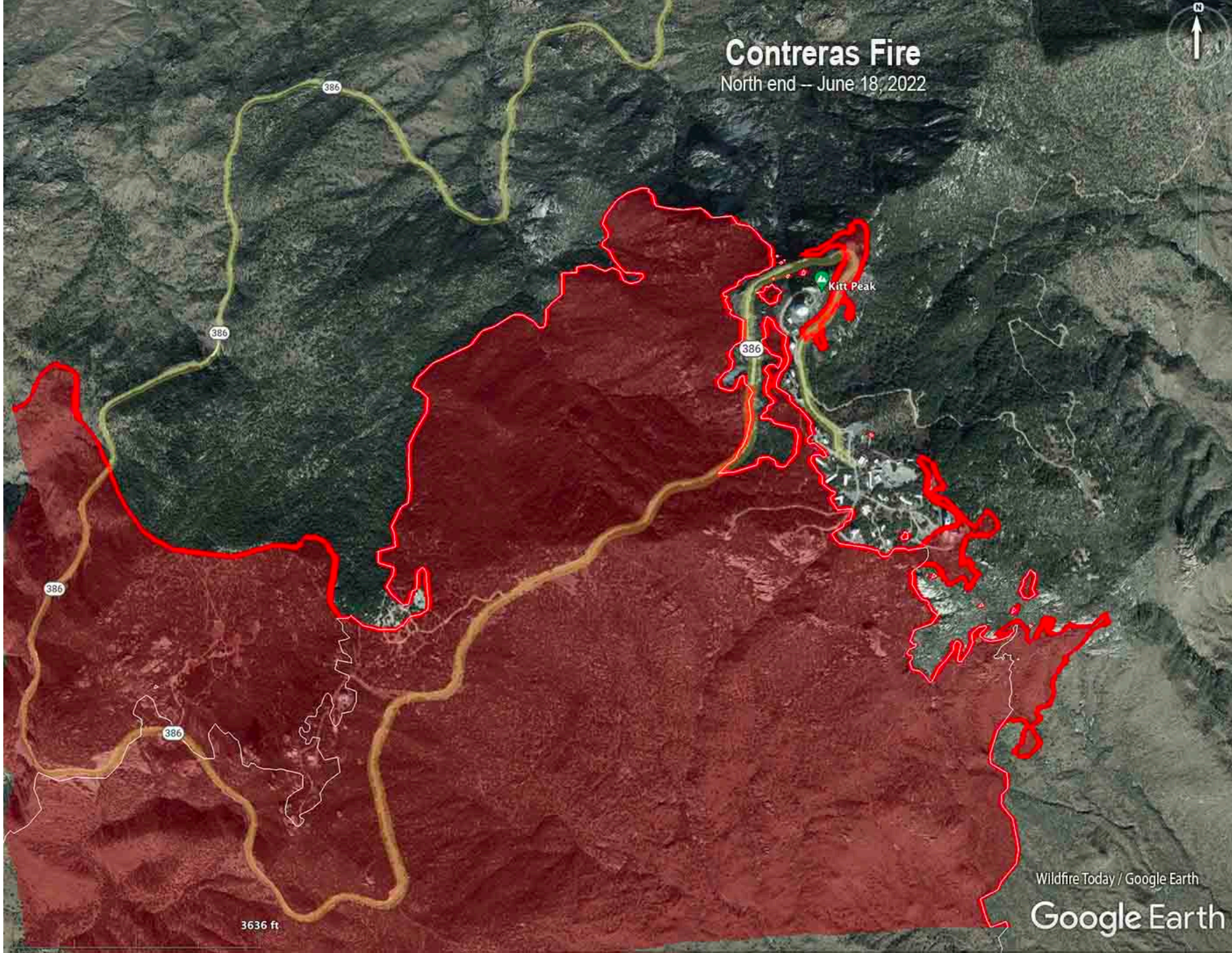


# Initial Install

- Success!
  - Got light into instrument and focused IFU channel on a star!
- Teamwork:
  - Yashvi Sharma
  - Josiah Purdum
  - Alex Reedy
  - Tyler Barna
  - Brendan King
- TODO:
  - install tri-prism
  - purge coolant lines
  - shake out software
- Hoped to shake out commissioning with temporary prism
- Install tri-prism in-situ when available

# Contreras Fire: June 11-24

# Contreras Fire: June 11-24



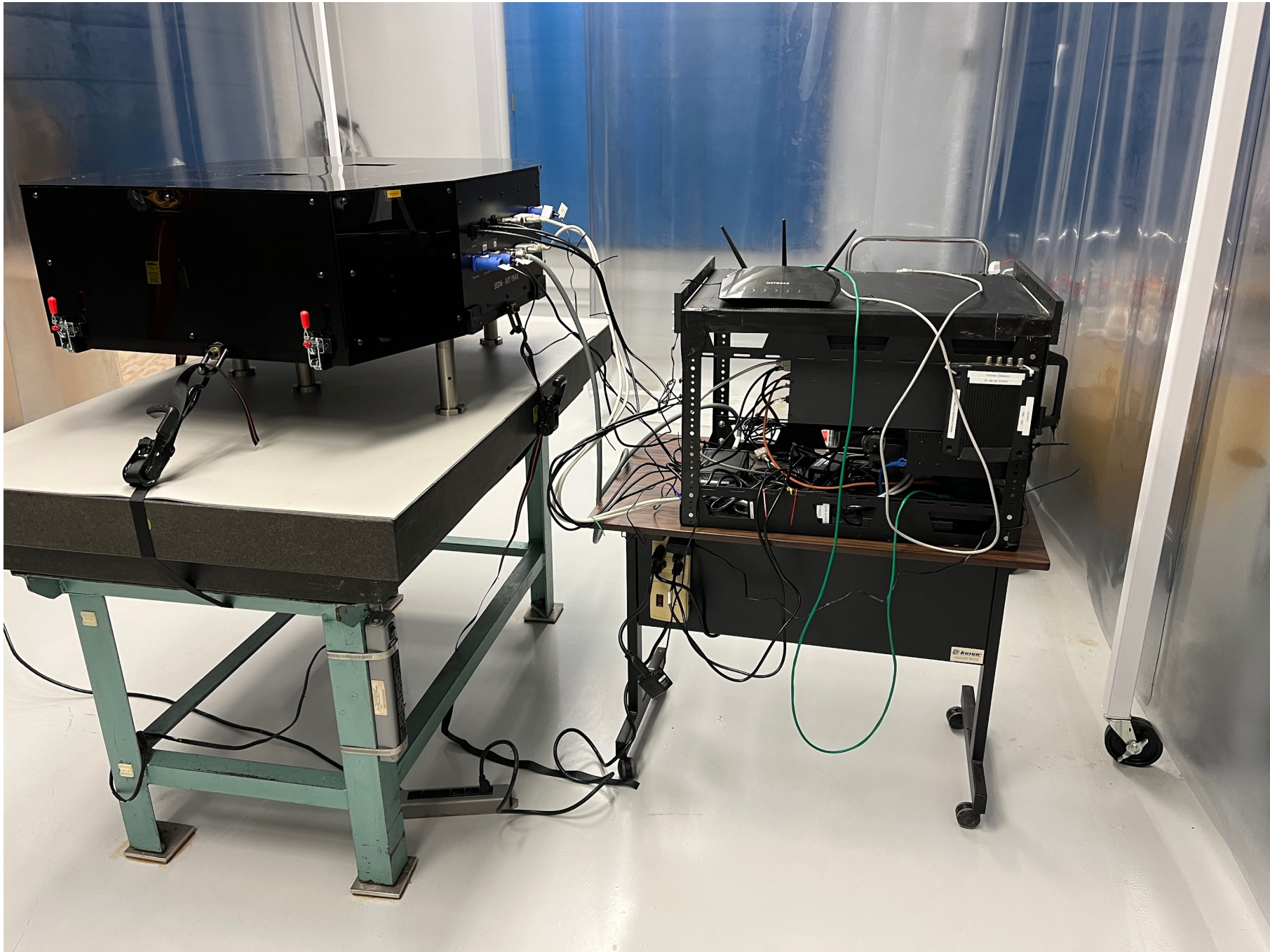
# Contreras Fire

- Observatories saved
- Power/internet lines torched
- Road damaged
- Monsoon more dangerous: rock slides
- Hiatus during Monsoon which extended into September

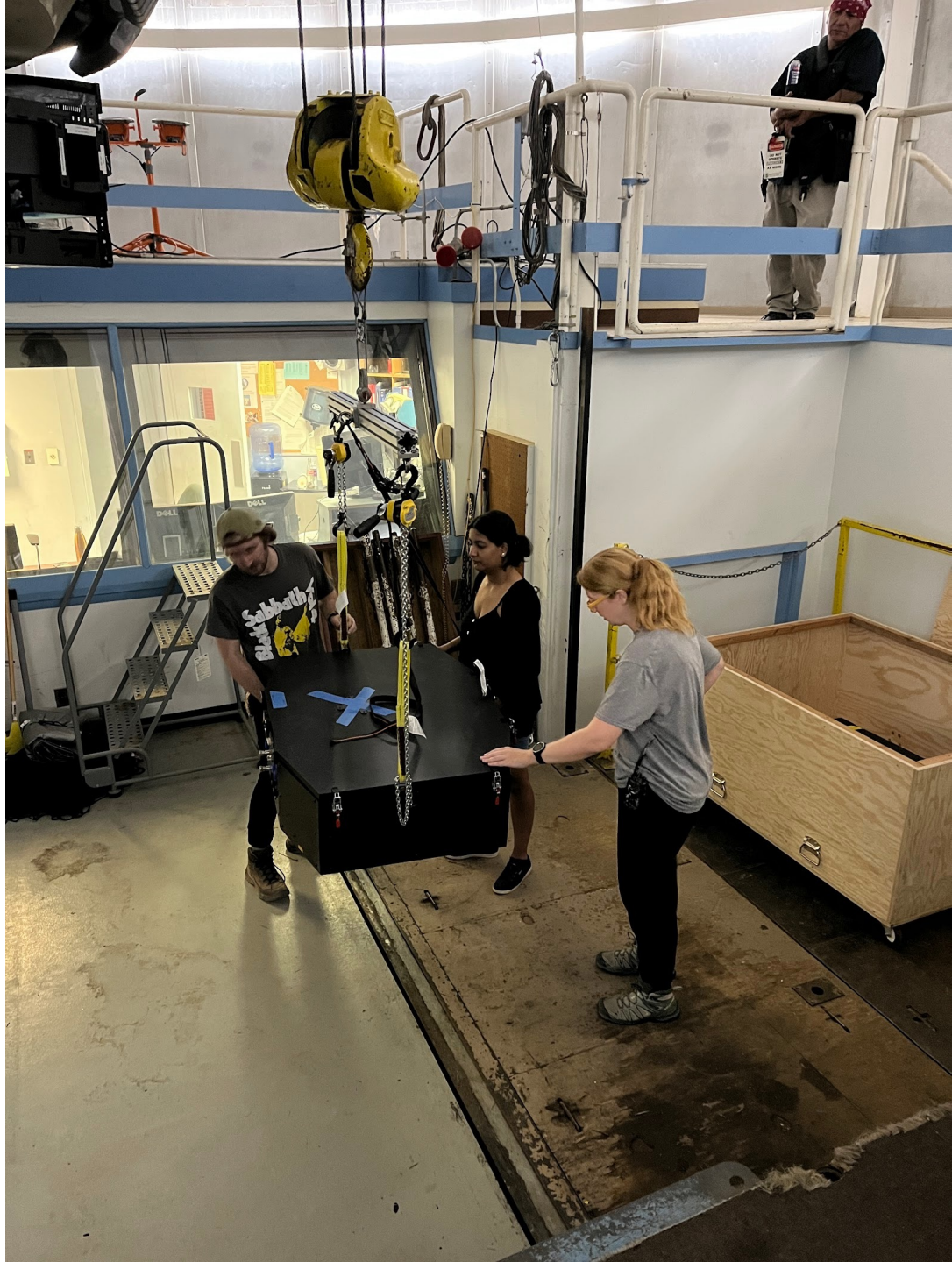
# Installation after a Fire: September 19

# Installation after a Fire: September 19

# Installation after a Fire: September 19



# Installation after a Fire: September 29



# Installation after a Fire: September 29

# Installation after a Fire

- Success!
- Teamwork:
  - Yashvi Sharma
  - Josiah Purdum
  - Alex Reedy
  - Jason Fucik: Tri-prism installation
  - Lauren Fahey: Tri-prism, electronics panel, coolant line installation

# Current Status

- Waiting for Power and Internet to resume
- Tri-prism installed and aligned
- Test cals taken: ok by inspection
  - Had to evacuate mountain before data could be copied
- Coolant lines purged
  - Better cooling than with fans
  - Got down to -72, but no further
- UPS needs to be replaced
- Using backup oil pump for RA axis (parts on order)
- Yashvi will give more details on commissioning status

# Current Status

- TODO List:
  - Shake out focus procedures for iXon/iKon
  - Shake out observing software
    - Implement guiding with iXon
  - Shake out scheduling/request software
  - Shake out DRP
  - Test cooling capability
  - Shake out data transfer
    - optimize to minimize costs
  - Define preventative maintenance tasks
  - Upgrade motor/encoders on KP2.1m
  - Facility upgrade tasks
    - A/C, paint, etc.